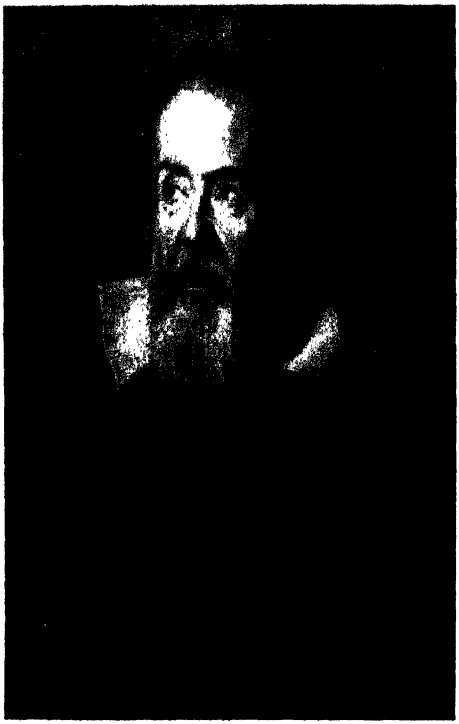


Alinari, photo

Art Repro Co

Galileo Galilei.

From the portrait by Sustermans in the Uffizi Gallery

# GALILEO
## HIS LIFE AND WORK

By J. J. FAHIE

MEMBER OF THE INSTITUTION OF ELECTRICAL ENGINEERS, LONDON, AND OF THE SOCIÉTÉ INTERNATIONALE DES ÉLECTRICIENS, PARIS

AUTHOR OF A HISTORY OF ELECTRIC TELEGRAPHY TO THE YEAR 1837 A HISTORY OF WIRELESS TELEGRAPHY, ETC.

WITH PORTRAITS AND ILLUSTRATIONS

LONDON
JOHN MURRAY, ALBEMARLE STREET,
1903

Wm. C. Brown
REPRINT LIBRARY
135 SOUTH LOCUST STREET • DUBUQUE, IOWA

" Sempre il novo che è grande appar menzogna
. . . al volgar debile ingegno;
Ma imperturbato il regno
De' saggi dietro all'utile s'ostina.
Minaccia nè vergogna
No 'l frena, no 'l rimove;
Prove accumula a prove!
Del popolare error l' idol rovina,
E la salute ai posteri destina."

—PARINI: "L'Innesto del Vaiuolo."

"Anything new, which is great, appears false to the ordinary weak mind, but the rule of the wise obstinately continues its way unmoved. Neither threats nor shame checks or changes its course; experiment follows experiment; the idol of popular error is thrown down, and health to posterity is ensured."

DEDICATED

TO

ANTONIO FAVARO

PROFESSOR IN THE ROYAL UNIVERSITY OF PADUA, AND DIRECTOR OF THE NATIONAL EDITION OF GALILEO'S WORKS, UNDER THE AUSPICES OF HIS MAJESTY THE KING OF ITALY

IN ADMIRATION OF THE RESULTS OF HIS 25 YEARS' ALMOST EXCLUSIVE DEVOTION TO GALILEAN LITERATURE AND AS A SLIGHT ACKNOWLEDGMENT OF THE HELP HE HAS GIVEN ME IN THE PREPARATION OF THIS VOLUME BY HIS OBLIGED FRIEND

THE AUTHOR

# PREFACE

THE history of the life and labours of Galileo is pregnant with a peculiar interest to the general reader as well as to the man of science and the philosopher. His brilliant discoveries the man of science regards as his peculiar property; the means by which they were made and the development of his intellectual character belong to the logician and the philosopher; but the triumphs and reverses of his eventful life must be claimed for our common nature, as subjects of deep interest and serious meditation.

So wrote Sir David Brewster in the opening paragraph of his biography of Galileo ("Martyrs of Science," London, 1841). It is the object of the present volume to give a fuller presentation, under this three-fold aspect, of the life which Sir David has only outlined.

In recent years materials for such a work have been brought together which were not accessible

when Brewster wrote. Imperfect collections of Galileo's writings were published in Bologna 1656, in Florence 1718, in Padua 1744, and in Milan in 1808-11 and 1832; but the first edition of anything approaching a complete character is that of Albèri in sixteen volumes, which was begun in 1842 and completed in 1856. That even this collection is defective in many important particulars is shown by the fact that another edition was begun in 1890, under the auspices of the King of Italy, and under the direction of Professor Antonio Favaro of the Royal University of Padua. Of this monumental work, twelve out of twenty large volumes have appeared. They contain all Galileo's works, the works of adversaries annotated by him, and his correspondence down to the year 1619, and supply an inexhaustible mine for the student of science. In exploring this for nuggets I have had the inestimable assistance of Professor Favaro, who has given me many valuable hints, and has generously placed at my disposal all his Galilean studies and researches for the last twenty-five years. Thus I am enabled to give a fuller and more comprehensive history of the life and work of Galileo than has hitherto been attempted, or, indeed, been possible. Thanks mainly to Professor Favaro and his multi-

tudinous writings, my book contains much new matter, and, what is more important, it avoids most, if not all, of the numerous errors and fables which previous biographers have little by little woven into the life of Galileo.

For the benefit of students who may wish to explore for themselves (and I promise them rich harvests), I have given at the end of this volume a short history of Galileo's writings, followed by a list of works which I have consulted, and which may be found useful. Speaking for myself, I have to acknowledge my special indebtedness to (besides the editions of Albèri and Favaro) the works of Nelli, Venturi, and Drinkwater, and, coming down to more recent times, those of Martin, Olney, Von Gebler, and Favaro. The works of Nelli, Venturi, Drinkwater, and Martin have been useful to me in a general way. Mrs Olney's charming volume and Favaro's "Galileo e Suor Maria Celeste" have been largely drawn upon for Galileo's private life, and for his correspondence with his daughter; while Martin, Von Gebler, and Favaro have been the chief guides in my account of Galileo's relations with the Roman Curia.

I have also to acknowledge my indebtedness to Mr Arthur Berry, of King's College, Cambridge,

who very kindly read the proofs and made suggestions of great value, which I was happy to adopt, and to Mr H. H. Champion, The School, Uppingham, for revising the scientific parts of my work. Mr Champion not only corrected a few errors and ambiguities into which I had fallen, but supplied most of the material on which my *résumés* of the Dialogues of 1632 and 1638 are based.

In my quotations of letters and documents I do not in all cases give them in full. I mostly content myself with extracts of the parts referable to the particular matter in hand. I think it necessary to point this out, as the quotations do not always show where the ellipses occur.

## CONTENTS

# LIST OF ILLUSTRATIONS

# GALILEO—HIS LIFE AND WORK

## CHAPTER I

### EARLY YEARS TO APPOINTMENT AS PROFESSOR IN PISA

### 1564-1589

Galileo Galilei, one of the earliest and, perhaps, one of the greatest of the experimental philosophers of the modern world, and the father of telescopic astronomy, is generally known in history by his baptismal name, Galileo, alone, in accordance with a custom of the Italians to call their great men by their Christian names, or by nicknames derived from some peculiarity of the individual or from the place of his birth.

Galileo, as we shall continue to call him, was descended from a noble family of Florence, which was long and honourably connected with the governing bodies of the republic, fourteen of its members having filled the highest posts on nineteen different occasions between the years 1343 and 1528.

The original surname of the family, Bonajuti, was exchanged for that of Galilei on the election,

in 1343, of one of its members, Tommaso, to the College of the XII Buonomini, or the Twelve Good Men, as the ruling body of the republic was then called. A grandson of this Tommaso, christened Galileo, became a celebrated physician, and, in 1438, was appointed Professor of Medicine in the University of Florence. He was elected one of the Priori, or governing body, on two occasions, in 1430 and 1434; and in 1445 he filled the office of Gonfaloniere or Chief Magistrate of the republic.

After a long and well-spent life he was buried with public honours in the Church of Santa Croce, Florence, where his grave is marked by a slab of white marble let into the floor of the nave, near the main entrance door. The stone bears a full-length figure in bas-relief of an old man, robed, and wearing the high folded cap used by the gentle folk and scholars of the period. On the breast lies a closed book, over which the hands are folded, and at the feet is a Latin inscription, setting forth that "This Maestro Galileo of the Galilei (formerly of the Bonajuti) was in his time the head of Philosophy and Medicine, who also in the highest magistracy loved the republic marvellously. His son, Benedetto, blest in the inheritance of his holy memory and well-spent and pious life, has appointed this tomb for his father, for himself, and for his posterity."[1]

Vincenzio, the father of our Galileo, was an impoverished descendant of this noble house, being the great-grandson of Michelangelo Galilei,

[1] Ruskin, "Mornings in Florence," p. 14, speaks of this as "one of the most beautiful pieces of Fourteenth (? Fifteenth) century sculpture in this world."

a brother of the above-named Maestro Galileo, and twice one of the Priori, in 1431 and 1438.

Vincenzio was born in 1520, and though, as we have just said, of broken fortune, he was well endowed on the intellectual side. He studied music under Zarlino of Chioggia, a seaport town fifteen miles south of Venice; but in after years he did not hesitate to attack the opinions of his old master in his "Dialogo della Musica Antica et della Moderna" (Florence, 1581), and "Discorso intorno alle opere di Gioseffo Zarlino" (Florence, 1589).[1]

These works display great knowledge and laborious research; and the first-named, especially, has been of much assistance to the musical historian of later days. One passage from the introduction may fittingly be noted here, as it shows the same spirit of free enquiry—free from authority and tradition—which pervades all the acts and writings of his distinguished son.

> "It appears to me," he says, "that they who in proof of any assertion rely simply on the weight of authority, without adducing any argument in support of it, act very absurdly. I, on the contrary, wish to be allowed freely to question and freely to answer without any sort of adulation, as well becomes those who are sincerely in search of truth."

Besides writing learnedly on the theory and practice of music, Vincenzio was especially distin-

[1] These and four other works of the same author are enumerated in Favaro's "Bibliografia Galileiana," Rome, 1896. Other essays, which were never printed, are now preserved among the Galileo MSS. in the National Library, Florence.

guished as an exquisite performer on the lute—an instrument which he tells us was then better manufactured in England than in any other part of Europe. He was also a skilful mathematician, and had an extensive acquaintance with the languages and literatures of Greece and Rome.

By his wife, Giulia Ammannati of Pescia, Vincenzio had three sons, Galileo, Michelangelo, and Benedetto, the last of whom died in infancy; and four daughters, Virginia, Anna, Livia, and Lena. Of Anna we know nothing, and of Lena very little.

Galileo, the eldest, was born in Pisa, where his father was engaged in commerce, on 15th February 1564—just three days before his famous fellow-countryman, Michelangelo Buonarroti, closed his eyes in Rome.

The first decade of Galileo's life, that is, down to about 1575, was passed at Pisa, where, in the frequent absences of the father on business, the family lodged with a relative named Muzio Tedaldi. In Pisa, then, and not in Florence as has hitherto been supposed, Galileo received his early education, partly at the school of one Jacopo Borghini, and partly at home, where his father helped him with his Greek and Latin lessons.

At about the age of twelve or thirteen Galileo was transferred to the far-famed monastery of Vallombrosa, near Florence, to go through a course of what, according to the time, constituted "the Humanities," or the literary education then considered indispensable for a well-born youth.

Supposed Birthplace of Galileo, in Pisa.

[*To face p.* 4.

Here he made himself acquainted with the best Latin authors, and also acquired a fair command of the Greek tongue, thus laying the foundation of the elegant and incisive style for which his writings are so distinguished. With one of the monks he began a course of instruction in logic, but from the first he appears to have had little taste for this subject, preferring what scraps of elementary science and philosophy he could pick out of the lessons.

From a contemporary document, first published by Professor Selmi in 1864,[1] it would seem that, while with the monks of Vallombrosa, Galileo was so far attracted towards a religious life as to have joined the novitiate of the Order; but his father, who had other designs for him, seized the opportunity of an attack of ophthalmia, and withdrew the boy from the monastery. A letter of Muzio Tedaldi to Vincenzio Galilei, dated 16th July 1579, and congratulating him on the removal of his son, seems to corroborate this story, and fixes the date with sufficient accuracy.

This lovely spot has for English readers another and more personal recollection. The Florentines are proud to this day to remind one that our Milton visited it more than once during his stay in Florence in the autumn of 1638 and the spring of 1639. It was with these visits in her mind that Elizabeth Barrett Browning wrote:—

> "Remembering Vallombrosa. Therefore is
> The place divine to English man and child,
> And pilgrims leave their soul here in a kiss."

It lies, as the name Vallombrosa imports, in a

1 "Nel Trecentesimo Natalizio di Galileo," Pisa, 1864.

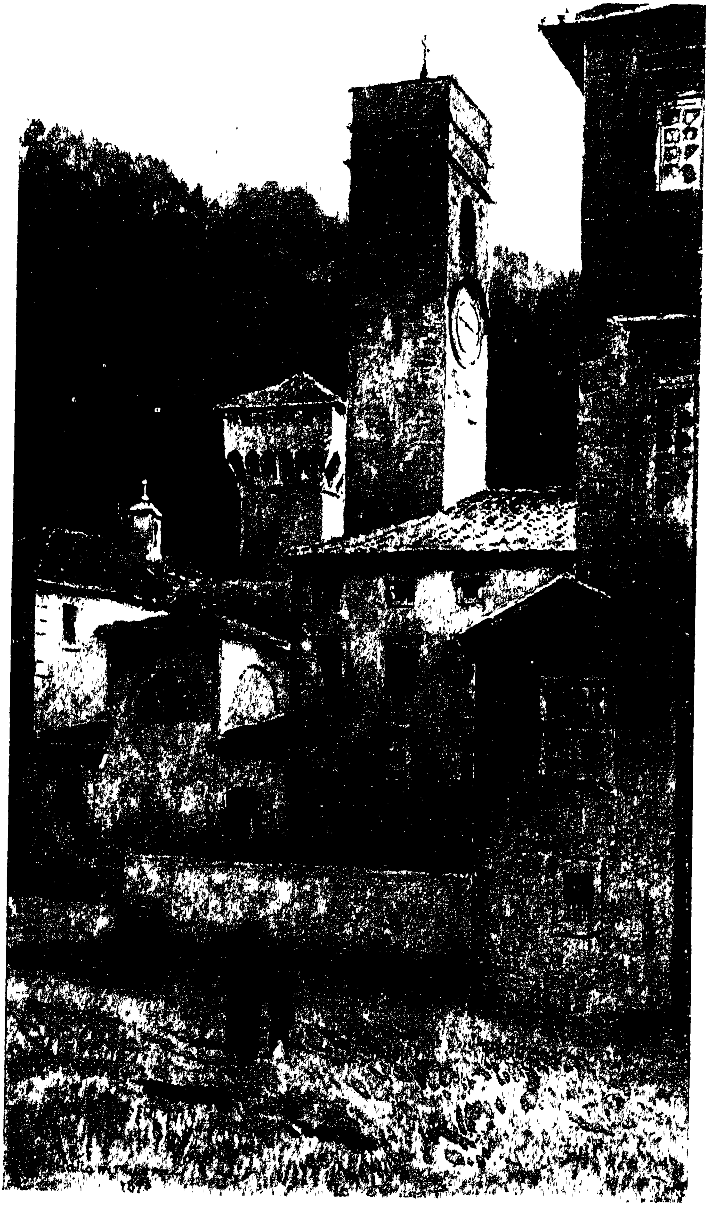
shady and sequestered vale. Hence Milton's lines descriptive of Satan calling:

> "His legions, angel forms, who lay entranced,
> Thick as autumnal leaves that strow the banks
> In Vallombrosa, where the Etrurian shades
> High over-arched imbower."
> —*Paradise Lost*, Book I. lines 301-4.

We have said that in withdrawing his son from Vallombrosa Vincenzio Galilei had other designs for him; but at first they were not very ambitious. Vincenzio, although of noble birth, had no property, his income from trade was scanty and precarious, and his family was large. Under these circumstances he destined his son to a career by no means distinguished, though one that conferred wealth on Florence, and therefore held in no small esteem by her citizens—the boy was to be a cloth-dealer.

Now it must be told that from his early boyhood Galileo was remarkable for intellectual aptitudes of various kinds, coupled with considerable mechanical inventiveness. His favourite pastime was the construction of toy-machines, not the less ingenious because they did not always work.[1] As he grew up he learnt from his father something of the theory and practice of music, and became so skilful with the lute as to excel him, good performer as he was, "in charm of style and delicacy of touch." He was also, it is said, a creditable performer on the organ and one or two other instruments, but the lute was his favourite, and continued to be so through life. As he found it a pleasure in youth, so it was a great

[1] It is interesting to note that Newton showed a similar precocity for things mechanical.



Monastery of Vallombrosa.

[*To face p.* 6.

solace in his later years—especially when blindness was added to his other afflictions.

In the sister art his talent was equally striking, and as a lad he showed considerable skill in drawing and painting. In later life he used to tell his friends that, had circumstances permitted him to choose his own career, he would have elected to become a painter. So well known was his youthful talent as draughtsman and colourist that such acknowledged artists as Ludovico Cigoli, Bronzino, Passignano, and Jacopo da Empoli, often sought his criticism of their works. Cigoli, in particular, was wont to say that Galileo alone had been his teacher in the art of perspective, and that whatever credit he enjoyed as a painter was owing to his advice and encouragement.

In his youthful days Galileo was also very fond of poetry, and later on in these pages we shall have occasion to notice his essays on Dante, Ariosto, and Tasso, as well as some verses and the fragment of a play, all of which bear witness to, at least, a cultivated taste.

In view of these great and varied abilities thus early displayed (to which we must not forget to add a good knowledge of Greek and Latin), the father could not help concluding that his son was born to be something better than a seller of cloths, and he now resolved upon a scientific career. As, however, it was necessary that the branch selected should offer a prospect of profit, and as he had himself had experience of the unremunerativeness of mathematics and music, the profession of medicine was decided on. Accordingly, on 5th September 1581,

when seventeen and a half years old, Galileo was sent to study medicine at the University of Pisa.[1] As before this time the family had returned to Florence the youth was placed as a boarder in the house of the relative before mentioned, Muzio Tedaldi, and at once took up the usual courses in philosophy and medicine, his teacher in the latter being Andrea Cesalpino, the celebrated physician and botanist, who filled the chair of medicine from 1567 to 1592.

Viviani, the first biographer of Galileo, and his last and best-loved disciple, tells us that our youth's attitude from the first in the philosophical classes was not at all to the satisfaction of his teachers, owing to the habit, inherited or acquired from his father, of examining an assertion to see what it was worth, instead of blindly accepting it on faith in the master, or in deference to authority.[2] In consequence of this unheard-of audacity in one so young, he soon acquired a reputation among the professors and his fellow-students for bold contradiction, and was dubbed "The Wrangler." His eager questioning of the dictates of Aristotle, Plato, St Thomas Aquinas, and other ancient lights, found no favour in their eyes. To the narrow conceptions of the time, a philosopher needed only to *know* Aristotle

[1] In order to reduce the expenses of a college training, Vincenzio tried to obtain for his son one of the forty free foundations for necessitous students attached to the University, but neither then, nor at the end of the third year, when the request was renewed, was the favour granted.

[2] In the first volume of Favaro's edition of Galileo's works, there are many pages of Juvenilia, or Commentaries (in Latin) on Aristotle's "de Caelo" and "de Mundo," which were written about 1584, and which are evidently notes of lectures he had been attending. They show the close attention of the young student.

by heart; *to understand* him was a secondary consideration; to contradict him was a blasphemy. Galileo, however, would try to understand, and often dared to contradict, and thus arose that feeling of hostility which ultimately, as we shall see, drove him from Pisa, and which endured for years after he became famous.[1]

In 1581 Galileo made his first discovery, which is characteristic of his observant eye. As the story goes, the student of eighteen was one afternoon performing his devotions in the Cathedral of Pisa, and in full view of Maestro Possenti's beautiful bronze lamp which hung (and still hangs) from the roof of the nave. In order to light it more easily the attendant drew it towards him, and then let it swing back. Galileo at first observed this simple incident, as thousands of other worshippers had done before him and have done since, *i.e.* in a casual way, but quickly his attention became riveted to the swinging lamp. The oscillations, which were at first considerable became gradually less and less, but, notwithstanding, he could see that they were all performed in the same time, as he was able to prove by timing them with his pulse—the only watch he possessed![2]

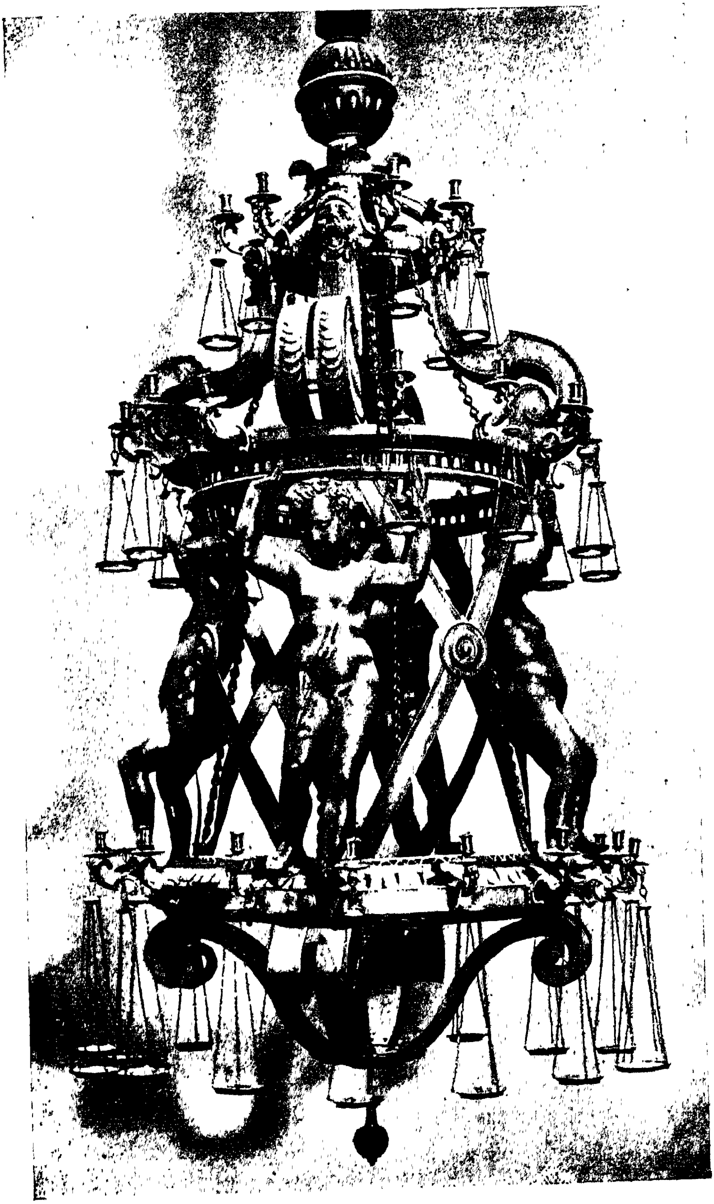
[1] Thus, Father Castelli, the first disciple and lifelong friend of Galileo, writing to him from Pisa in November 1613, says: "Of our controversies (on the earth's motion) not a word is allowed to be said —a thing which astonishes me. Your marvellous discoveries are scarcely known here even by name."

[2] Whether this be only a pretty fable, like that of Newton and the apple, cannot now be decided, but it is, at least, certain that Possenti's lamp was not the one which Galileo observed, since it was not made until 1587, and was only hung in its present place on the 20th December in that year.

After some experiments at home, he saw that an instrument might be constructed on this principle which should mark with accuracy the rate and variation of the pulse. He gave shape to the idea, and, imperfect though the instrument was, it was received with wonder and delight by the physicians of the day, and was long in general use under the name of Pulsilogia. Santorio, who was Professor of Medicine at Padua, has given representations of four different forms of this instrument (in his "Methodi Vitandorum Errorum in Arte Medica," Venice, 1607), three of which we reproduce.

Fig. 1 consists merely of a weight at the end of a string, which is held at the top of a graduated scale. The string being gathered up into the hand till the vibrations of the weight coincide with the beatings of the patient's pulse, the length is ascertained from the scale, which if great indicates a languid, and if small, a more lively action. In Fig. 2 the improvement is introduced of connecting the scale and string; the length of the latter is regulated by turning a peg, and a bead on the string shows the measure. Fig. 3 is still more compact, the string being adjusted by winding (or unwinding) upon an axle at the back of the dial-plate. More than half a century later, as we shall see in the course of our narrative, Galileo utilised the same principle of the pendulum in the design of an astronomical clock.

Up to the time of which we are treating, the study of mathematics, although mentioned in the *rotuli* of the schools, was practically neglected in Italy. The names of Euclid and Archimedes



Possenti's Lamp in the Cathedral, Pisa.

[*To face p.* 10.

were little more than empty sounds to the students who thronged the lecture halls of Pisa, of Bologna, and even of learned Padua. Furthermore, Galileo's

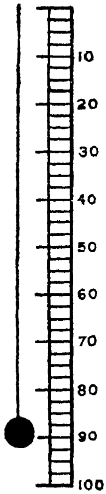



Fig. 1

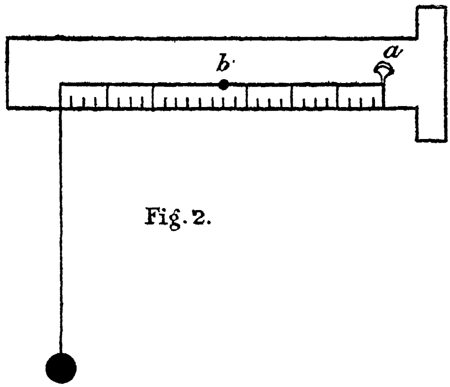



Fig. 2.

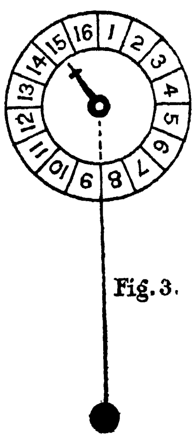



Fig. 3.

DIAGRAMS OF THE PULSILOGIA.

father, thinking that such studies by one intended for the medical profession would be a waste of

time, not only abstained from teaching the boy what he knew himself, but endeavoured to prevent his obtaining the knowledge from other sources, assuring him that it would be time enough when his medical studies were finished. Thus, up to the close of his nineteenth year, Galileo knew little or nothing of mathematics. But—

> "There's a divinity that shapes our ends,
> Rough-hew them as we will."

The natural and as yet hardly suspected bent of the young man's mind now asserted itself, and in a way not to be mistaken.

During the winter and spring of 1582-83 the Court of Tuscany, according to custom, was residing at Pisa, and among the suite was one Ostilio Ricci, an able mathematician, tutor to the Grand-ducal pages, and a friend of Galileo's family in Florence. Naturally, the tutor and the young student became friends. Going on one occasion to pay Ricci a visit, Galileo found him engaged in giving a lesson to the pages on some problems in Euclid. He did not enter, but, standing behind the door, followed the lesson with a strange attention. This was the beginning of a new sensation, a craving of the intellect, under the influence of which he found himself drawn repeatedly to the pages' class-room. Each time, entering unobserved and concealing himself behind a door, he listened, Euclid in hand, to the teacher's demonstrations. Henceforth mathematics were more studied than medicine, for which, truth to say, he never had any relish. Then, taking courage and confessing his sin of curiosity, he begged the astonished

tutor to help him, which Ricci readily consented to do.[1]

When Vincenzio learnt, as he did through Ricci, that his son was devoting himself to Euclid to the neglect of Hippocrates and Galen, he did his utmost to divert the young man from this (as it seemed to him) unprofitable study.[2] But in the end old Vincenzio had to learn the unconquerable power of genius, and had to submit to it, just as the father of the great Michelangelo had to submit, and under very similar circumstances, one hundred years before.

Vincenzio's consent was probably hastened by other considerations. With his large family and small means he must have found it increasingly difficult to keep his son at college. At any rate, at the end of the third year (1584) he again petitioned the Grand Duke, Ferdinando I., for one of the forty free places founded in aid of poor scholars; but, owing to the hostility (to which we have already referred) caused by "The Wrangler's" general attitude and his marked disrespect for "authority," the petition was refused. Thereupon, after nearly four years' residence, and without taking the doctor's degree, Galileo was withdrawn from the University, and returned to the parental roof in Florence. This would be about the summer of 1585.

[1] Professor Favaro, the latest and most accurate of Galileo's biographers, is inclined to doubt this story, but, as they say in Italy, *Se non è vero, è ben trovato.*

[2] Vincenzio's horror of mathematics or pure science as a means of obtaining a living is justified by the fact that while the Professor of Medicine in the University of Pisa received 2000 scudi a year, the Professor of Mathematics had only 60 (£13) a year, or just 7½d. a day!

Here, and chiefly under the guidance of Ostilio Ricci, he devoted himself heart and soul to mathematics and physics. From the study of Euclid he passed on to the writings of Archimedes, whose work in mechanics he was destined to continue, and for whom he then conceived a veneration which lasted through life.

In 1586, when fresh from the study of the great Syracusan, Galileo constructed the hydrostatic balance (*la Bilancetta*), for ascertaining with accuracy the relative weights of any two metals in an alloy. His short essay, descriptive of this instrument, was circulated in MS. amongst his friends, and was published for the first time, after his death, in 1644.

He refers to the popular account of the way in which Archimedes detected the fraud committed by the goldsmith in the making of Hiero's crown. The story is well known, but will bear repeating as illustrative of some of the ways of scientific discovery.

> "What great things from small may be springing
> Is proved by the engine's deep sob;
> And yet, after all, the beginning
> Was the kettle that sings on the hob."
>
> —J. E. CARPENTER, *Songs.*

Hiero had given a certain weight of gold to be made into a crown. When the work was finished a suspicion arose in the royal mind that the gold had been alloyed with some baser metal, and he applied to Archimedes in the hope of detecting the supposed imposture. The weight of the crown being correct, the problem was to measure its bulk;

for silver being, weight for weight, of greater bulk than gold, any alloy of the former, in place of an equal weight of the latter, would necessarily increase the bulk of the crown. To measure the bulk, the only known method for testing the purity of the metal, was difficult without melting it into a regular figure.

Archimedes, after many unsuccessful attempts, was about to abandon the search altogether, when the following circumstance suggested to his discerning and prepared mind a train of thought which led to the solution of the difficulty. Stepping into his bath one day, his mind doubtless fixed on the object of his research, he chanced to observe that, the bath being full, a quantity of water of the same bulk as his body must flow over before he could immerse himself. He probably perceived that any other body of the same bulk would have displaced the water equally; but that another body of the same weight, but less bulky, would not have produced so great an effect. In the words of Vitruvius, "as soon as he had hit upon this method of detection, he did not wait a moment, but jumped joyfully out of the bath, and, running forthwith towards his own house, called out with a loud voice that he had found what he sought. For as he ran he called out in Greek, 'Eureka! Eureka!' I have found it out! I have found it out!" When his emotion had sobered down, he proceeded to investigate the subject calmly. He procured two masses of metal, each of equal weight with the crown—one of gold, and the other of silver; and having filled a vessel very accurately with water, he plunged into it the silver,

and marked the exact quantity of water that overflowed. He then treated the gold in the same manner, and observed that a less quantity of water overflowed than before. He next plunged the crown into the same vessel full of water, and observed that it displaced more of the fluid than the gold had done, and less than the silver, from which he inferred that the crown was neither pure gold nor pure silver, but a mixture of both.

Galileo doubted the correctness of this story, for he says, the results of such a method are fallacious, or, at least, little exact. After much thought on the subject, he devised a "most exact" method, which he believed was really the one employed by Archimedes himself.

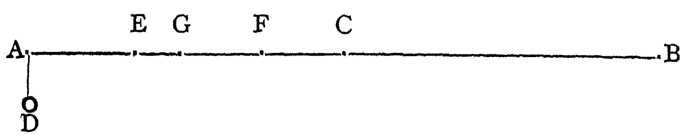



Fig. 4.

Take a lever AB, Fig. 4, at least a yard long (and the longer it is, the more accurate will be its indications), delicately suspended from its centre C; and at the ends let there be means of attaching the body (say an alloy of gold and silver) to be tested at B, and its counterweight at A. First, take a piece of pure gold and weigh it in air; now immerse it in water; it will seem lighter, and the counterpoise D must be moved from A to, say, E, to obtain a balance. Then, as many times as the space CA contains the space AE, so many times is gold heavier than water. Proceed in the same way

with a piece of pure silver. When placed in water, it will seem to lose more of its weight than the gold did, and its counterpoise will have to be moved to, say, F, showing that silver is specifically less heavy than gold in the ratio AE to AF.

Now taking the alloy, it is clear beforehand that it will weigh less than an equal volume of pure gold, and more than an equal volume of pure silver. Weigh it in air and then in water, when it will be found that its counterpoise must be moved to some point between E and F, say G. From this we learn that the weight of gold in the mixture is to that of the silver as FG is to GE.

After his work on the hydrostatic balance, Galileo undertook an investigation of the centre of gravity in solid bodies, the results of which were embodied in an essay,[1] which obtained for him the title of "The Archimedes of his time," and which, with his previous work on the pendulum, the hydrostatic balance, and one or two shorter papers, made his name favourably known in Italy. Among those to whom he thus became known we must here mention one who was ever afterwards his warm friend and patron, the Marquis Guidobaldo del Monte of Pisaro, already himself a distinguished mathematician. Struck by the originality displayed in Galileo's essays, Guidobaldo opened a scientific correspondence with the author, and took an early opportunity of introducing him to the notice of

[1] "Theoremata circa centrum gravitatis solidorum," first circulated in MS. copies, and printed in 1638 as an appendix to his "Dialogues on Two New Sciences."

Ferdinando I., Grand Duke of Tuscany, as a young man of whom the highest expectations might be formed.

This recognition of his rising talent was, of course, very gratifying to the young man, but it was a poor substitute for the gains of a practising doctor, on which old Vincenzio had calculated, to eke out his scanty income. Galileo himself saw this, and, with the object of helping to maintain his family, he gave private lessons in mathematics and mechanics to students in Florence and the neighbouring town of Siena.[1] But his great ambition was to obtain a professorship in one of the Universities, for which Italy was then and still is famous. Accordingly, on the Professorship of Mathematics in the University of Bologna falling vacant (middle of 1587), Galileo made every endeavour to secure it, but without success. The post was given to Giovanni Antonio Magini, with whom we shall meet later on, nominally as a friend of our hero, but in reality one of his crassly irreconcilable adversaries.

Late in 1587 Galileo made his first journey to Rome, for what purpose history does not say, but probably with the object of finding there some opening, or in furtherance of his designs on the chair at Bologna, which was still vacant, Magini's induction dating only from 4th August

[1] About this time, 1587-88, we hear of Galileo reading two papers before the Academy of Florence, on the site and dimensions of Dante's "Inferno," a subject which just then was being hotly discussed by the *literati* of the Tuscan capital. For this task he was specially chosen by Baccio Valori, the president, a fact which shows that his reputation as a literary connoisseur was as well established, as that he was an able mathematician.

1588. However this may be, the visit was not without result, for it led to his acquaintance with Father Cristoforo Clavio, of the Society of Jesus, already a celebrated mathematician, and to whom the world is mainly indebted for the reform of the calendar in 1582. Little did they then think that the learned old Jesuit would be a stout opponent of the new astronomical teachings which the younger man would promulgate, but to which, before his death in 1612, he was to become a distinguished convert, *malgré lui.*

Evidently while in Rome the two new friends had been discussing mathematics, for on his return to Florence Galileo sent a letter to Clavio, under date, 8th January 1588 (the earliest of his letters known to exist), in which he frankly states a difficulty respecting the demonstration of a certain theorem (*lemma*). Those, he says, to whom he had already submitted it, were not satisfied; therefore he could not be so himself. In this dilemma, he solicits the learned father's opinion, adding that if it, too, was unfavourable, he should not rest until he had found such a demonstration as would be convincing to all.

Galileo, always anxious to be earning something, next applied for the Professorship in Padua University, rendered vacant by the death of Moletti in January 1588, and in this connection he betook himself to Venice; but again he was unsuccessful. Soon after, a similar post at Pisa, his *Alma Mater*, became vacant, and, taking advantage of his recent introduction to the Grand Duke, in whose gift the

appointment was, he applied for it through the Marquis del Monte. Once more he was unfortunate, as the following letter of 16th July 1588 to the Marquis shows.

"My wish regarding Pisa, about which I wrote your lordship, will not be carried out; for I hear that a certain monk, who lectured there formerly, and then, on being made General of his Order, retired, has resigned the Generalship, and has again taken to lecturing; and that his Highness has already appointed him to the post.

"Now, as here in Florence there was formerly a Professorship of Mathematics, which was established by the Grand Duke, Cosimo I., and which many among the nobles would like to see revived, I have petitioned for it, and hope to obtain it through your illustrious brother's influence, to whom I have entrusted my case. As there have been foreigners here, with whom his Highness has been engaged, I have not been able to speak on the subject myself, and, therefore, I beg you to write again and mention my name."

Even in this fourth attempt he failed. Thus for nearly two years, from about the middle of 1587 to the middle of 1589, Galileo saw all his efforts to obtain employment in his own country end in bitter disappointment. Can we wonder that, repulsed at Bologna, Rome, Padua, Pisa, and Florence, he should turn his thoughts towards the East as to a land of promise? From some documents recently brought to light by Professor Favaro, the indefatigable editor of the latest collection of Galileo's works, it appears that he was actually engaged on this desperate enterprise at the moment when at last the tide of fortune began to flow in

his favour.[1] Towards the end of May 1589, Galileo and a young Florentine patrician of his acquaintance, Ricasoli Baroni, had decided to seek together their fortunes in the East, when the Mathematical Professorship at Pisa again fell vacant. Once more he made application for the post, and in due time, and through the joint influence of the Marquis Guidobaldo and his brother, Cardinal Francesco Maria del Monte, he was awarded the prize. This was in July 1589, when he was barely twenty-five and a half years old. To be sure, the salary was insignificant, only 60 scudi per annum, or about £13 of our money. Moreover, the appointment was only for three years, but renewable. But, any port in a storm; and in Galileo's needy circumstances, even this wretched salary was not to be rejected; besides, the office would enable him to make something in addition by private tuition.

[1] See Favaro's "Galileo e Suor Maria Celeste," Florence, 1891, p. 25.

# CHAPTER II

## GALILEO, PROFESSOR IN PISA

## 1589-1592

No sooner was Galileo settled in his new office than he resumed, and with increased diligence, his physico-mathematical researches. In the first year he carried to greater length his previous studies on the centre of gravity, and arrived at results which excited afresh the admiration of the Marquis del Monte; he discovered that peculiar geometrical curve to which he gave the name cycloid, and attempted the problem of its quadrature;[1] and all the while he was steadily revolving those novel ideas on motion, which were creeping into his mind, and which were to be the basis of his greatest and latest work. In pursuance of these ideas, he now began a systematic investigation (with experiment) of the mechanical doctrines of Aristotle.

Galileo was not the first to call in question the

[1] The cycloid is the curve described by a point in a circle (as the nail in the rim of a carriage wheel) while it makes one revolution along a horizontal base. Soon after its discovery, and on Galileo's recommendation, it was applied in the formation of the arches of the bridge (Ponte di Mezzo) over the Arno in Pisa. Galileo guessed that the area contained between the cycloid and its base is three times that of the describing circle, but he was unable to demonstrate this geometrically—a task which his disciple Torricelli achieved soon after his death.

authority of Aristotle in matters of science. It is now known that the celebrated painter, Leonardo da Vinci (1452-1519), held many views opposed to the Aristotelian philosophy, and even anticipated Galileo in some of his discoveries. But as da Vinci's scientific writings (mostly short notes and memoranda) remained in manuscript, practically lost to the world, till 1797,[1] it is not likely that his views were known to any one. Also Nizzoli, Varchi, Benedetti, and others, had attacked in a general way, or in particulars, the peripatetic doctrines.

While, therefore, Galileo was not the first to question the authority of Aristotle, he was undoubtedly the first whose questioning, as embodied in his acts and writings, produced an effect in men's minds which it would not be exaggerating to call a revolution. The reason is not far to seek. The spirit of free thought and free enquiry was asserting itself in every department. As in the reformation of religious doctrines, so in science, men were beginning to shake off the old superstitions. Galileo, in a word, came at the psychological moment, and, above all, he came armed with a weapon of convincing force—experiment. He was not content, like his precursors, with merely giving an opinion, supported or not by wordy metaphysical arguments, but what he asserted as well as what he denied he *proved* to ocular demonstration.

The results of his researches—the foundations

[1] When Venturi brought them to notice in his "Essai sur les Ouvrages Physico-Mathématiques de Leonard da Vinci," Paris, 1797.

of dynamical science—are given at great length in his treatise "De Motu Gravium," 1590, which, as was his custom then, and for many years after, was circulated in manuscript, and only appeared in print two hundred years after his death.[1] As most of these early theorems were afterwards developed and incorporated in his larger work, "Dialogues on Two New Sciences" (1638), we shall reserve our notice of them till we reach that period of his life. Here, then, we need only say, that as fast as he succeeded in demonstrating the falsehood of any of Aristotle's positions he did not hesitate to denounce them from his professorial chair, and perhaps with too much energy, at least for his own comfort, since the immediate result was to irritate more and more his colleagues of the academic body, who, as we have seen, were never too well disposed towards him.

We must, however, say something here of his celebrated experiments on falling bodies, on account of their associations with the Leaning Tower of Pisa —one of Italy's many curious monuments. Nearly two thousand years before, Aristotle had asserted that if two different weights of the same material were let fall from the same height, the heavier would reach the ground sooner than the lighter in the proportion of their weights. The experiment is certainly not a difficult one, but nobody thought of that method of argument, and consequently this assertion was received upon Aristotle's *ipse dixit* among the axioms of the science of motion.

[1] In Albèri's "Opere di Galileo Galilei," 16 vols., Florence, 1842-56; or better, Favaro's new edition, where they are given more accurately, and for the first time published completely.

Galileo, however, now appealed from the authority of Aristotle to that of his own senses, and maintained that, with the exception of an inconsiderable difference due to the disproportionate resistance of the air, they would fall in the same time. The Aristotelians ridiculed and refused to listen to such an idea. But Galileo was not to be repressed, and determined to make his adversaries see the fact as he saw it himself. So one morning, before the assembled University, professors, and students, he ascended the leaning tower, taking with him a 10-lb. shot and a 1-lb. shot. He balanced them on the over-hanging edge and let them go together. Together they fell, and together they struck the ground.

Neglecting the resistance of the air, *i.e.* supposing the bodies to fall in a vacuum, Galileo had found them to be subject to the following laws :—

1. All bodies fall from the same height in equal times.

2. In falling the final velocities are proportional to the times.

3. The spaces fallen through are proportional to the squares of the times.

The correctness of the first law was easily established by the leaning tower experiments, and the better to prove the others he devised the inclined plane—a long straight piece of wood, along which a groove was accurately made, and down which a bronze ball was free to move with the least friction. With this he proved that, no matter what the inclination of the plane was, and, consequently,

no matter what the time was, the movement of the ball was always in accordance with the laws.[1]

It might have been thought that such experiments as these would have settled the question decisively. Aristotle, the master, would certainly have accepted them in disproof of his own dogma, but his disciples were embued with no such frankness, and would not be convinced. With the sound of the simultaneously fallen weights ringing in their ears, they still persisted in maintaining that a weight of 10 lbs. would reach the ground in a tenth of the time taken by one of 1 lb., *because* they were able to quote chapter and verse in which Aristotle assured them that such is the fact!

A temper of mind like this could not fail to produce ill-will towards one who felt no scruples in exposing such folly. With the exception of the new Professor of Philosophy, Jacopo Mazzoni, the whole body of the teaching staff, as well as the heads of the University, now turned against our young iconoclast.

For some time these feelings of animosity had no serious effects, but, no doubt, Galileo was "boycotted" and subjected to many petty annoyances. Soon, however, a wholly unforeseen circumstance came to the aid of the Aristotelians, and led to Galileo's retirement from Pisa. Giovanni de Medici, the natural son of Cosimo I., was at the time Governor of Leghorn. He had a bent for mechanics, and was not unskilled as an engineer

[1] Naturally these experiments would show the necessity of some accurate measurer of time, and so we are not surprised to learn that Galileo again occupied himself with the pendulum as such a measurer. See Favaro's "Galileo e Suor Maria Celeste," p. 32.

and architect. Amongst other contrivances, he had just designed a monster dredging machine, which he wished to employ in clearing the harbour of Leghorn. A model was submitted to the Grand Duke, by whom Galileo was commissioned to examine and report upon it. He did so, and declared it to be useless, an opinion which subsequent experiment (with an actual machine) fully confirmed. That the discomfited inventor should be mortified at this failure is natural; but that he should for no other reason be angry with Galileo, and should seek to injure him, is not so intelligible. However, so it is stated, and the young prince was easily induced to join hands with the Aristotelians in an onslaught on their common aversion. Hisses were now heard at his lectures; cabals were started at Court; and, altogether, the position speedily became so intolerable that Galileo resigned his post, before the three years' term had expired, and once more returned to Florence. This was about the middle of 1592.

Other circumstances of an economical character, no doubt, contributed to this decision. We have seen that out of his salary of £13 per annum he was expected to contribute (and did so willingly) to the support of the family; but miserable as the stipend was, he seldom received the whole of it. It was the custom in Pisa to put the professors under stoppages for all lectures not given, and at the end of the scholastic year they were, as a rule, called upon to refund a sum corresponding to the number of lectures missed, and proportional to the salary. Now, owing to an inundation of the Arno, Galileo

was unable to take up his post on the opening day of the session; and on another occasion, while in Florence on some urgent business, a sudden illness of his mother detained him some days over the specified time, yet, although he wrote to the head of the University explaining the causes of his detention in each case, the rule was rigorously enforced—in the first year to the extent of one-tenth of his salary![1]

Indeed, his retirement from Pisa was no new or sudden resolution. He had not been many months there, when the ever-pressing money difficulty, and the undisguised antipathy of his colleagues, made him think of throwing up the post. Thus, it appears from his correspondence with the Marquis del Monte that early in 1590 he sought his friend's aid in obtaining the Mathematical Chair of Padua, which was vacant since January 1588 by the death of Moletti; but at this time as well as later (early in 1592) his efforts were not successful.

To this period belong most of Galileo's literary productions. His "Capitolo in Biasimo della Toga," written in 1590, is a fragment of a play, an amusing though somewhat licentious burlesque, in which he ridicules the University ordinance compelling the professors to wear the gown, not only

[1] To eke out his pittance Galileo had to give up much of his time to the drudgery of private lessons. On the strength of a letter to his father, dated 15th November 1590, and asking for a copy of the works of Galen, some of his biographers conclude that he was then practising as a physician, or reading with medical students; but it is more likely, as Professor Favaro says, that "Galen was wanted, not for the purpose of coaching, but for the many anti-Aristotelian arguments which the work contains" ("Galileo e Suor Maria Celeste," p. 26.)

when actually engaged in lecturing, but when passing through the streets and visiting their friends. This was another cause of offence to the academic body, and the author was set down as a man of easy morals, and little mindful of the professorial dignity.

About the same time Tasso's "Jerusalem Delivered" was being hotly criticised at the Accademia della Crusca of Florence. This celebrated academy, the first of its kind, and still flourishing, was founded 1582 by Cosimo I., Grand Duke of Tuscany, to maintain the purity of the Italian language, or, as the name (Crusca = bran) imports, to sift the flour from the bran. In the exercise of this praiseworthy object the academy often gave offence by condemning all works which did not conform to its rules, and among the works thus censured was the "Jerusalem Delivered" of Torquato Tasso. Galileo must be held to have contributed to this result by his very severe critique on the style, construction, and characters of the poem. He is said to have known by heart the "Orlando Furioso" of Ariosto, whom he called the *divine*, but, according to all competent critics, his appreciation of the one is as excessive as his disparagement of the other.[1] The following sentences will give an idea of this too scathing production: "I am sometimes aghast at the foolish things this poet sets himself to describe." "To my mind this poet is poor and miserable

[1] His copy of the "Orlando Furioso" has been preserved. It is full of notes and corrections which critics say are just and ingenious. See "Postille all' Ariosto" in Albèri's vol. xv., or Favaro's vol. ix.

beyond all expression, whereas Ariosto is rich, magnificent, admirable." "Eh, Signor Tasso, you understand nothing of your art, you besmear much paper and only make in the end pap for cats." In later life Galileo considerably modified his views, but still could only relish Tasso after Ariosto "as one relishes cucumbers after melons."[1]

Besides these effusions, Galileo has left us the outline of a comedy in prose, for writing which some of his biographers blame him much, and still more for preserving it; also a number of sonnets, some of which are of doubtful authenticity, and ought, perhaps, to be credited to his son Vincenzio, a MS. volume of whose verses, dated 1637, is now in the Riccardian Library, Florence. Amongst his friends in later life was Antonio Malatesti, the poet and friend of Milton, to whom a copy of his "Sphinx," or poetical enigmas, was presented. This curious and somewhat irreverent work has prefixed a number of commendatory verses, amongst which is a sonnet by Galileo on the telescope, which he presented to the Grand Duke.[2] This and three other sonnets have been printed in Albèri's edition, 1842-56, since

[1] See his letters of 5th November 1639, and 19th May 1640, both addressed to his friend, Francesco Rinuccini. At the time Tasso was under restraint in a kind of *maison de santé*, and this controversy with the della Cruscans grievously wounded him. But in the end it tended more to spread the knowledge, and with that knowledge the fame, of his "Gerusalemme Liberata," than permanently to injure it. For a long time it was thought that Galileo's essay, "Considerazioni al Tasso," had perished, till the Abbe Serassi discovered a MS. copy about 1780, whilst collecting materials for his "Life of Tasso," published in Rome in 1785.

[2] "Notes and Queries" (1853), vol. viii. p. 295, where the verses are given.

which Professor Favaro has collected three others, and a longer piece which, from internal evidence, he assigns to the period of Galileo's professorship in Pisa, 1590-92. This we venture to reproduce as a fair specimen of our philosopher's versification recently brought to light.

"Oh poveri Dottor mal arrivati!
Voi siete stati pure i bei minchioni
A dare agli scolar tanti capponi,
Con rischio d'esser tutti condennati.

"Qui non si guarda che sien mandati
Editti, Bandi, Prescrizioni;
Qui non val nulla Monsignor Capponi
Per dio, n'avete ad esser gastigati.

"Venite quà; non è una vergogna,
Un vituperio espresso, una pazzìa,
Un obbrobrio da mitera e da gogna,

"Avere i polli in casa, e darli via
Senza ragione e quando non bisogna,
A chi viene a cantar la Befanìa?

"E poi a una genìa
Che per saziar loro ingordigia ìnterna
Avrian data la stretta a vita eterna?

"In questa lor Taverna,
Cioè congrega di gran Tavernieri,
Hanno condotto un Conte, ed un Alfieri,

"Che son due masnadieri,
Chè l'un de' ghiotti è Re, l'altro è Monarca:
Guai a colui che con costor s'imbarca!

"S' egli entravan nell' Arca,
Dove campò Noè co' suoi parenti,
E con tutte le razze de' viventi,

"Non crediate altrimenti
Che le spezie si fusser propagate,
Che si poteva dir, le son sonate;

"Perchè queste brigate
Non pur mangiavan le starne e gli storni,
Le pecore, le capre e i liocorni,

"Ma in que' quaranta giorni
Asini e buoi morivan tutti quanti,
Orsi, draghi, serpenti e liofanti.

"Hanvi poi tanti e tanti
Cavalier da far prove memorande
Intorno ai piatti, intorno alle vivande,

"Che sarìa cosa grande
Dir del Mannelli l'ingordigia orrenda,
O del Sertin da quella gran faccenda

"Dir la furia tremenda,
Un rasciugar di piatti, e d'altri vasi
Dell' Ansaldi, del Medici e del Masi.

"Hannovi anco quel Rasi;
Di questo non occorre far parola,
Perchè ognun sa ch' ei tira ben di gola.

"Or da costor m'invola
Con quel bocchino, e coi leggiadri sguardi
Quel tristo Trafuriel di Carlin Bardi.

"Che venne alquanto tardi,
Essendo stato fino alle tre ore
Non so dal Confessoro o dal Dottore;

"E vi giuro di cuore
Che mi parea con quello spadaccino
Qualche San Giorgio, o qualche San Martino.

"Evvi anco un Lupicino,
Che divora, trangugia, anzi tracanna;
Il nome solamente lo condanna."

Early in 1591, Virginia, the eldest of Galileo's sisters, was married to Benedetto Landucci, son of the Tuscan ambassador at Rome during the pontificate of Leo X. Writing to his father on 26th December 1590, this most loving of brothers says:—

"I am preparing for Virginia a set of silken bed-curtains, the silk for which I bought at Lucca, and have had it woven at little cost, so that, although the stuff is one and a quarter yards wide, it only cost me about three carlini the yard. The stuff is made with selvage, and will be sure to please. I am now having made the silk fringes for ornamenting the curtains, and could also have the bedstead made if desired. I beg you not to speak of this in the house, as I wish it to be an unexpected surprise. I will bring them at the Carnival holidays, and, if you wish, I could also bring enough to make four or five vests of damask and velvet of an exquisite design."

Not content with this present, which, considering his scanty means, was more than liberal, he further bound himself in the marriage contract to provide a *dot*, the non-payment of which, as we shall see, brought on him no end of sordid annoyances—his ungracious brother-in-law going so far as to threaten him with prison.

On his return to Florence (middle of 1592) Galileo's position was truly pitiable. Without employment, and with no immediate prospect of obtaining it, the monetary situation must have appeared to him overwhelming, aggravated as it was by the death of his father on 2nd July 1591. Besides his mother, there was a brother, Michelangelo, who had received a good musical education from his father, but who had not yet been able to contribute anything towards the household expenses; and two sisters, Livia and Elena—all entirely, or almost entirely, depending on him for their daily wants.

# CHAPTER III

## GALILEO, PROFESSOR IN PADUA

### 1592-1610

In our second chapter we saw that Galileo long had designs on the Mathematical Chair in Padua, which had been vacant since January 1588, another fact which shows the little value that was attached to pure science even in learned Padua.[1] Now he again approached his friend, the Marquis del Monte, on the subject. Del Monte was a distinguished pupil of the Padua University, had many friends there, and also a relative who was high-placed in the military service of the Venetian republic. With letters of introduction from this influential man, Galileo set out for Venice towards the end of the summer of 1592, all his worldly goods (as he used afterwards to tell his friends) being contained in a trunk which did not weigh 100 lbs. He passed through Pesaro, the home of his noble friend and patron, and halted at Padua, where he was warmly received by Gianvincenzio Pinelli, a learned man of Genoese extraction long domiciled at Padua, and an intimate friend of del Monte. Armed, further, with recommendations from Pinelli, Galileo arrived in Venice

[1] See remarks on this subject, p. 10 *ante*.


Façade of the University, Padua, *tempo* Galileo.

[To face p. 34.

about 1st September, and was met with the alarming intelligence that a formidable rival was already in the field, namely, Giovanni Magini, whom we have before mentioned as the Professor of Mathematics in Bologna, whose term there was about to expire, and who was long known to have aspired to the Chair at Padua. However, with the aid of his friends, del Monte and Pinelli, and of *their* friends in Venice, Galileo had the good fortune to be selected. Being informed privately of this happy issue, he set out on 20th September for Padua, *en route* for Florence, to wind up his affairs there, and to obtain the permission of his sovereign to withdraw from Tuscany.

On 26th September he was gazetted, and as the terms of the diploma (preserved amongst the Galilean MSS. in the National Library, Florence) will serve to show the estimation in which our philosopher was held, we reproduce it here.

(After preamble.) "Owing to the death of Signor Moletti, who formerly lectured on Mathematics at Padua, the Chair has been for a long time vacant, and, being a most important one, it was thought proper to defer electing any one to fill it till such time as a fit and capable candidate should appear. Now there has been found Domino Galileo Galilei, who lectured at Pisa with very great honour and success, and who may be styled the first in his profession, and who, being ready to come at once to our said University, and there to give the said lectures, it is proper to accept him. Therefore, the said Domino Galileo Galilei is hereby appointed Mathematical Lecturer in our University for four years certain, and two uncertain (and the last two are to be at the will and pleasure of our Serenity), with the yearly salary of 180 florins."

The gaining of this coveted post over so formidable a rival as Magini was, of course, very gratifying to the *amour propre* of Galileo, but it was also very welcome from the money point of view. The salary was exceptionally good for the time,[1] and, owing to the large number of students who flocked to Padua, he would be able to add considerably to his income by private lessons.

The Paduan session opened on 1st November, but, unlike his treatment at Pisa, our new professor was allowed ample time to settle his affairs in Florence, and to prepare his inaugural address, which was to be worthy alike of the occasion and the man. Accordingly, on 7th December 1592, Galileo entered on his new duties with a discourse which is said to have won the greatest admiration, not only for its profound knowledge, but for its eloquence and elegance of diction. It is thus referred to, and evidently by one who heard it, in Tycho Brahé's "Astronomiae Instauratae Mechanica," 1598.

"Interea, Gallilaeus de Gallilaeis Florentinus Professionem Mathematicam hic adeptus est, qui suarum lectionum septimo Decembris initium fecit. Exordium erat splendidum in magna auditorum frequentia. Datae Patavii 28 Decembris, Anni 1592."

For some time after his arrival at Padua, Galileo was apparently the guest of Pinelli, whose library of, it is said, 80,000 volumes would be useful in prepar-

[1] It was still very much under the salaries attached to the other chairs. Thus, the Professors of Philosophy and of Civil Law received annual stipends of 1400 and 1680 florins respectively.

ing his inaugural address. He then appears to have established himself in a modest house in the vicinity of the Church of San Giustina, on the Prato della Valle (now Piazza Vittorio Emmanuele). Little did he then think as he strolled about the Prato, then a *Grande Place* for *fêtes* and spectacles of all kinds, that his statue would be one of seventy-seven which would be erected in years long after to commemorate great men who had made Padua illustrious for all time.

During the first few years at Padua, Galileo displayed an extraordinary and versatile activity. He wrote a number of treatises, chiefly for the use of his pupils, among the larger of which may be mentioned: On Military Architecture, on Fortifications, on Mechanics, on the Sphere, on Accelerated Motion, on Gnomonics. All of these attained a wide circulation in manuscript copies; some were not printed until long afterwards, while others, like the paper on Gnomonics, are unfortunately lost. Others, again, strayed beyond the pupils and friends for whom they were intended, and found their way into the hands of persons who did not scruple to claim and publish them as their own.

Galileo's treatise on Mechanics ("Della Scienza Meccanica"), written in 1594, deals with the powers of the lever, pulley, and screw, and concludes with an account of the Archimedian Screw for raising water, followed by a short fragment "On the Force of Percussion."

In the introductory remarks Galileo demonstrates the important principle of Virtual Velocities, which, according to Professor Jack, marks, with his laws of

falling bodies, the greatest advance in mechanical science since the world began. Here, perhaps, it will be best described in the popular language of Professor Jack:—

"It was in connection with his investigations of motion on a plane that Galileo laid down the principle that, perhaps, serves best as the basis of the theory of balancing forces, the principle of what is called Virtual Velocities. Every one is familiar with it, in the ordinary maxim, that what is gained in speed is lost in power. In the board laid across a fallen tree, on which children see-saw, the lighter child is put at the extremity of the longer arm. With a plank 12 feet long, a child 50 lbs. weight will be balanced against one 70 lbs. weight when the plank rests on the tree 7 feet from the light child's end, and 5 feet from the heavy one's. When they swing the amount of swing is proportional to the distances from the fixed point. If the plank moves, so that the child at the 7 feet end rises through 7 inches, the other goes down through 5. In every case like this, where forces are in equilibrium on a system, we can imagine a motion given, every point moving according to the geometrical circumstances. Let us imagine such a motion. When two forces act on a system and keep it at rest, multiply the space through which the point of application of each force moves, referred to the line in which the force acts, by the measure of the force. When there is equilibrium the resulting quantities are equal and of opposite signs. The one child weighing 50 lbs. rises vertically through 7 inches, and we may call the product 350 inch-lbs. upwards. The 70 lbs. child moves in the same time 5 inches downwards, and the product, which is 350 inch-lbs. downwards, is equal and opposite to the other. If there is equilibrium it must always be so; if it is so

there must be equilibrium. It is to Galileo that we owe this most fruitful of statical principles. It can easily be extended to the case when any number of forces act at any number of points on a body or a system; but it was not till a century later that John Bernouilli could state it in all its generality, or show how admirably it serves as a sufficient basis for the whole theory of equilibrium."[1]

The treatise on the Sphere, which was first published at Rome in 1656 (fourteen years after Galileo's death), is supposed by some authors to be apocryphal, as it teaches the Ptolemaic cosmogony, placing the earth immovable in the centre, and adducing the usual arguments. But this does not make the work necessarily apocryphal, for we have it under his own hand that for some years he taught the Ptolemaic system in his classes out of compliance with popular feeling, although at heart he was a follower of Copernicus.[2]

In his first letter to Kepler, dated 4th August 1597, and acknowledging the receipt of the latter's "Mysterium Cosmographicum," he says:—

"I have as yet read nothing beyond the preface of your book, from which, however, I catch a glimpse of your meaning, and feel great joy on meeting with so powerful an associate in the pursuit of truth, and, consequently, such a friend to truth itself; for it is deplorable that there should be so few who care about truth, and who do not persist in their perverse mode of philosophising. But as this is not the fit time for lamenting the melancholy condition of

[1] "Nature" (1879), vol. xxi. p. 40.

[2] Maestlin, Kepler's master, did the same, while all the time he was well known to be a Copernican.

our times, but for congratulating you on your elegant discoveries in confirmation of the truth, I shall only add a promise to peruse your book dispassionately, and with the conviction that I shall find in it much to admire.

"This I shall do the more willingly because many years ago I became a convert to the opinions of Copernicus,[1] and by his theory have succeeded in explaining many phenomena which on the contrary hypothesis are altogether inexplicable. I have arranged many arguments and confutations of the opposite opinions, which, however, I have not yet dared to publish, fearing the fate of our master, Copernicus, who, although he has earned immortal fame among a few, yet by an infinite number (for so only can the number of fools be measured) is hissed and derided. If there were many such as you I would venture to publish my speculations, but since that is not so I shall take time to consider of it."[2]

In the early summer of 1593 Galileo contracted an illness, which nearly proved fatal, and from which he suffered at intervals all through life. A party of three young men (so Viviani tells the story), of whom Galileo was one, "were enjoying at an open window in the country a current of air which was artificially cooled by a fall of water. They, unfortunately,

[1] See also the "Dialogues on the Two Systems of the World," second "Day," where Sagredo tells how he was led in early life to adopt the Copernican doctrine, and where Galileo evidently describes his own mental evolution.

[2] This interesting letter was the beginning of the friendship of these two great men, which lasted uninterruptedly till 1630, the date of Kepler's death. There is a still earlier admission in his letter of 30th May 1597, to his friend Professor Mazzoni of Pisa.

fell asleep under its influence, and so great was its effect on Galileo's hitherto robust constitution that a severe chronic disorder ensued, which showed itself in acute pains in the body, accompanied by frequent hæmorrhages and loss of appetite and sleep. The others suffered still more severely, for one died in a few days, while the third became deaf and died in a short time after."

Professor Favaro has been at great pains to corroborate this strange story, and has succeeded in giving it a more matter-of-fact appearance. He has identified the place as the Villa in Costozza, which is not far from Vicenza, and which then belonged to the Count da Trento. The Villa still exists, and in one of the rooms on the first floor he found an opening to a narrow passage or tunnel which led to a neighbouring cavern. The air issuing from this cavern is always cool (Favaro found it to be 52° Fahr.), and, perhaps, sometimes poisonous, like the Grotto del Cane, near Naples, so celebrated for its mephitic vapours. This would explain the disastrous results of sleeping under its influence which befell Galileo and his companions.[1]

While carrying on his professorial duties, giving private lessons, and writing learned tracts, Galileo was occupying himself profitably in other ways. Thus it would appear that his skill as an engineer was often in request by the State, for which he is said to have designed, or super-

[1] Favaro's "Galileo e Suor Maria Celeste," pp. 49-53.

intended the construction of, various works and machines.[1] Amongst the latter may here be noted a machine for raising water, of small dimensions but of great power, so that one horse could raise the water and distribute it through twenty channels. For this the Venetian republic gave him the exclusive use for twenty years, under a patent dated 15th September 1594; but, although it was tried with success in the garden of the Contarini Palace in Venice, it never came into much use.

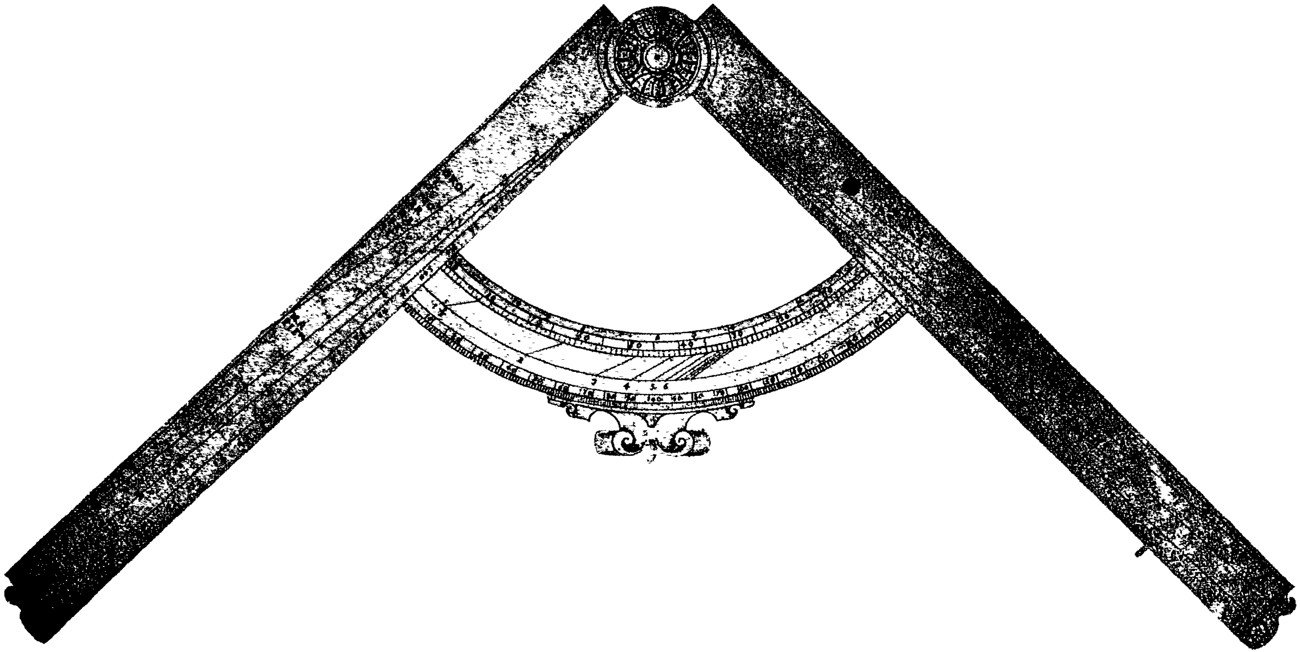
About 1596-7 he invented a more profitable instrument, his Geometrical and Military Compass. This useful instrument is now called the Sector, and is to be found in most cases of mathematical instruments. It consists of two straight rulers connected by a joint so that they can be set to any required angle. On one face are four pairs of lines.

*Arithmetical lines*, which serve for the division of lines, the solution of the Rule of Three, the equalisation of money, the calculation of interest.

*Geometrical lines*, for reducing proportionally superficial figures, extracting the square root, regulating the front and flank formations of armies, and finding the mean proportional.

*Stereometrical lines*, for the proportional reduction of similar solids, the extraction of the cube root, the finding of two mean proportionals, and for the transformation of a parallelepiped into a cube.

[1] So say Viviani and Gherardini in their biographies of Galileo, but Professor Favaro, after a diligent search among the archives of Venice, could find nothing to bear out the statement. For this and other cogent reasons he doubts its accuracy.



Geometrical and Military Compass.

[To face p. 42.

*Metallic lines*, for finding the proportional weights of metals, and other substances, for transforming a given body into one of another material and of a given weight.

On the other side of the instrument are :

*Polygraphic lines*, for describing regular polygons, and dividing the circumference into equal parts.

*Tetragonical lines*, for squaring the circle or any other regular figure, for reducing several regular figures to one figure, and for transforming an irregular rectilineal figure into a regular one.

*Joined lines*, used in the squaring of the various portions of the circle and of other figures contained by parts of the circumference, or by straight and curved lines together.

There is joined to the compass a quadrant, which, besides the usual divisions of the astronomical compass, has engraved on it a squadron of bombardiers, and, in addition, transversal lines, used for taking the inclination of a scarp of a wall.

From the encouraging reception given to this invention, orders for which came from all parts of Europe, Galileo determined to open a workshop in his own house, no doubt in order that the manufacture of this and other scientific apparatus[1] might proceed uninterruptedly under his personal supervision, and so be less liable to piracy. This we gather from an entry in his Day-book under 5th July 1599.

[1] His papers show that large numbers of the Geometrical and Military Compass, in copper and silver, were manufactured, and that he was also making magnetic compasses, and various kinds of drawing instruments.

"Messer Marcantonio Mazzoleni, mechanician, comes to reside in my house to work for me, and at my cost, on mathematical instruments, I undertaking to bear the expenses of him, his wife, and child, and to pay him in addition the sum of six ducats per annum."

This is one of the instances, before referred to, where Galileo's manuscripts and ideas got into the hands of people who were not ashamed to publish them as their own, and to denounce the author as an impudent plagiarist. Some years after the invention, finding that his right to it was being disputed, Galileo published a description of it and dedicated the book to his pupil, Prince Cosimo, son of the Grand Duke of Tuscany.[1] This was speedily followed by another book, the production of Baldassare Capra, a young Milanese, in which he claimed the invention as his own, and accused Galileo of piracy.[2] The matter was brought before the University authorities, and Galileo was able to show that he had made the invention as early as 1597, and had explained its construction and uses to numerous persons in Padua and elsewhere, amongst them being Capra himself! These statements were supported by depositions of well-known men, as Gio. Fran. Sagredo, Giacomo Badovere, Mazzoleni (Galileo's mechanician), Giacomo Alvise Carnaro, and Fra Paolo Sarpi.

[1] "Operazioni del Compasso Geometrico e Militare." The dedication is dated Padua, 10th July 1606. This is his first printed work.

[2] This work is entitled "Usus et Fabrica Circini Cujusdam Proportionis," Padua, March 1607. A modern writer speaks of Capra as "one of those parasites who live at the expense of the talent and the renown of others." Chasles: "Galileo, sa Vie et son Procès," Paris, 1862, p. 20.

The last-mentioned only need be quoted. Writing from Venice under date 20th April 1607, he affirms and attests that he had carefully compared the two works in dispute, and had found Capra's to be little more than a Latin translation of Galileo's Italian. He then goes on:—

"I further affirm that about ten years ago in Padua Signor Galileo showed me the instrument (described in his book) and explained its uses; and that about two years later, the said Signor made me a present of one, which I still have in my possession."

As Capra made no defence, the University authorities did not take long to decide. Under date 4th May 1607, they unanimously decreed that his book was a scandalous plagiary and an insult to Galileo and the University (of which Capra was a member); that all the copies in the possession of the author and his publisher, to the number of 483, be given up to them for suppression "in the way that seems best"; and that proceedings be taken against the printer and publisher.

Galileo afterwards published a full account of this affair in his "Difesa contro alle Calunnie ed Imposture di Baldassare Capra." The first part is taken up with a defence of his views on the new star of 1604, which Capra had attacked in another publication—moved thereto, as Viviani says, "by envy of the universal applause which accrued to Galileo from his lectures on the subject."

From the opening passages of Galileo's "Il

Saggiatore" (1623), it would appear that the real author of the book which went under Capra's name was Simon Mayer, a German graduate of Padua, whom we shall meet with later on arrogating to himself the merit of two of Galileo's astronomical discoveries. On this occasion, as soon as he found our philosopher intent on resenting the injury, he hastily quitted Italy, leaving his friend Capra to bear alone the shame of the exposure which followed.

In September 1598, the first period of Galileo's appointment expired, which the Venetian Senate were in no hurry to renew formally; not because of any doubt as to the incumbent's fitness, but because of the dreaded increase of salary which was usually expected on re-appointment, and which all governments like to evade if they can. Galileo himself had allowed the first term to expire, and had nearly completed one year of the second, before taking any steps in the matter. Then, about the middle of 1599, with the advice and assistance of Pinelli, Gianfrancesco Sagredo, a young Venetian of great promise, and other friends, he formally requested that his appointment be renewed, on an increased salary, as a precedent for which he cited the case of Professor Magini at Bologna, who on re-appointment was awarded a salary much in excess of that enjoyed by Galileo at Padua.

The question of augmentation was apparently long and stoutly opposed on one side, and as hotly pressed on the other. The Doge, Contarini, complained that he was pestered on the subject,

not only by Galileo's friends, but by his own household. "If Galileo," he cried, "is not content with his salary he can resign." Moletti, he pointed out, had never more than 300 florins, and it was an understood thing that the Professors should eke out their incomes by private lessons. In the end the appointment was renewed, on 28th October 1599, for a further period of six years, commencing 27th September 1598. The salary was fixed at 320 florins (about £70), and Sagredo was grumblingly bidden to warn his friend not to expect any further augmentation, "as the Senate did not choose to make his case a precedent for every learned and hungry foreigner who might think fit to press a similar claim."

Galileo's reputation as a teacher was now widely spread over Europe, and numbers of young foreigners flocked to Padua to attend his lectures. Amongst these are noted the Archduke Ferdinand, afterwards Emperor of Germany; the Landgrave of Hesse; the Princes of Alsace and Mantua; and a Prince Gustavus of Sweden, often confounded with the great Gustavus Adolphus. Our own William Harvey, the discoverer of the circulation of the blood, was a student at Padua, 1598-1602, and would no doubt be a frequent attendant.

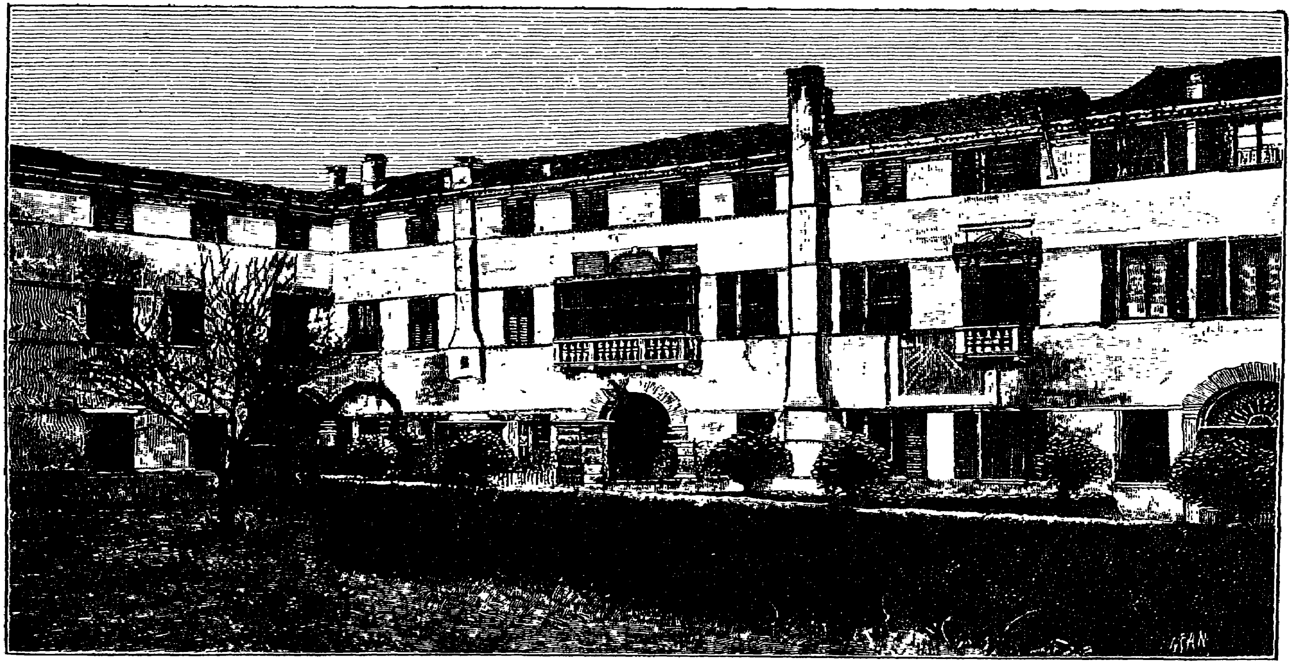
It is not certain when he moved from his modest house near the Church of San Giustina; but towards the end of 1599 we find him installed in a large house in the Via Vignali, now Via Galileo. Here he was able to accommodate suitably his private pupils, of whom he now

had large numbers resident with him, both Italians and foreigners. His private papers show that he looked after the catering himself, which must have been no light matter, seeing that he often had as many as twenty boarders at a time, some of whom were accompanied by servants or followers of some kind. Inclined to be prodigal by nature, Galileo made nothing out of his pupils' keep, being content if their contributions covered the expenses of house-keeping.

With the house went a garden, to which in 1603 he added an adjoining piece of ground containing a large arbour and vine-trellises. The care of this garden, the flowers, the fruits, the vines, was his great delight. He saw to everything and did much himself in the way of weeding, pruning, tying. Indeed, all his life he was very fond of gardening, which he followed as much as an education as a recreation and distraction from severer studies. Here he took his pleasure, sometimes alone, revolving deep things in philosophy, but more often surrounded by groups of his friends, or pupils, whom he now sported with, now charmed with performances on the lute, which he touched with a master's hand—

> "As sweet and musical
> As bright Apollo's lute, strung with his hair,"

now conversed, as they strolled along the arbour and under the spreading vines, on any subject that presented itself—the germination of seeds, the nutrition and vegetation of plants, the making of wines, philosophising all the while "from grave to gay, from lively to severe." We can



Galileo's House in Padua, back view from Garden.

[*To face p.* 48.

imagine how charming and instructive his conversations were, for Galileo had the habit of allowing no natural phenomena, however trivial in appearance, to escape him, and he found the advantage of this in his lectures and writings, as it furnished him with a stock of homely illustrations to which the daily experience of his hearers and readers readily assented, and which he could show to be identical in principle with the matter in hand. Thus he could always find—

> "Tongues in trees, books in the running brooks,
> Sermons in stones, and good in everything."

"We seem to see him now," says Favaro, writing within gunshot of the sacred garden, "under the trellis of vines cared by his own hands, surrounded by loving friends and pupils, and discoursing with them on divine philosophy; or presiding at an evening meal in summer spread under the grateful shade of trees or arbour; or playing the lute, as he was always ready to do in convivial meetings. Oh! how the remembrances of such evenings passed with Galileo in his pleasant garden under the vault of our splendid sky must have impressed themselves on the memories of the youth of Italy, France, England, and Germany, who came to Padua to listen to our great master."[1]

Among the crowd of noble and learned men, with whom at this period Galileo had cemented a friendship which was only to be severed by death, may be mentioned (besides Pinelli) Fra Paolo Sarpi of the Order of Servites, Theologian

[1] "Galileo e Suor Maria Celeste," p. 73.

and Counsellor of the Venetian Republic, and afterwards known as the Machiavelli of Venice; Fra Fulgenzio Micanzio, Sarpi's devoted friend and colleague; Fabrizio d'Acquapendente, the famous surgeon of Padua, who has been called "the Columbus of the human body," and under whom our great Harvey studied; Antonio de Medici; General del Monte; and young Gianfrancesco Sagredo, who developed into "a witty and eccentric patrician, whose house at Venice resembled a Noah's ark, containing all manner of beasts.". Pinelli took an opportunity of his correspondence with Tycho Brahé to recommend Galileo "as a man whose friendship would be worth while cultivating." Tycho addressed a letter to Galileo, under date 4th May 1600, but the acquaintance went no farther, and the great Dane died at Prague, 13th October 1601.

To the name of William Harvey, whom we have mentioned above as, probably, a friend of Galileo, we may now add the names of a few others of English and Scotch nationality, as, Robert Fludd, "The Father of the English Rosicrucians," who was studying in Padua *circa* 1602; Messrs Moore and Willoughby, both of whom are mentioned by Coryat in his "Crudities," the one as a doctor of physic, and the other as a learned student in the University. Richard Willoughby was one of Galileo's resident pupils, and evidently did him credit, for amongst the thousands of armorial bearings, etc., of distinguished members of the University which cover its walls, appears that of Willoughby; and a still

greater compliment was paid him by the Master in the presentation of a copy, with an autograph inscription, of the "Difesa contro. . . . Baldassare Capra." A little later, Galileo had two Scotch pupils who were among his most devoted friends. These were John Wodderborn (or Wedderburn), whom we shall meet with later on as his master's champion; and Thomas Seggett, who was also a friend of Kepler, and in whose "Album Amicorum," now in the Vatican library, Galileo inscribed his name.[1] Their coats-of-arms and memorial tablets are also on the University walls.[2]

To this period (1602) may be referred Galileo's invention of the air thermometer. The date is uncertain, for while Viviani asserts that the instrument was designed during the first term of his Professorship at Padua (1592-98), other evidence, on which Galileo rested his claim when contested some years later, will only carry us back to about 1602. Thus, Castelli, writing to Ferdinando Cesarini, 20th September 1638, says:—

"I remember an experiment which our Signor Galileo had shown me more than thirty-five years ago. He took a small glass bottle about the size of a hen's egg, the neck of which was two palms

[1] Under date 13th August 1599. Galileo's signature, followed by a few verses referring to the telescope and the discovery of Jupiter's moons, is also in Brinck's album (under year 1614), and, curiously enough, is next to that of Cardinal Bellarmine. The verses are given in "Notes and Queries," January 1858, p. 44.

[2] Professor Darwin gives the names of one hundred English and Scotch students to whom memorial tablets are erected. See his "Monuments to Cambridge Men at the University of Padua." (*Cambridge Antiquarian Society Proceedings*, March 1894.)

long (about 22 inches), and as narrow as a straw. Having well heated the bulb in his hand, he inserted its mouth in a vessel containing a little water, and, withdrawing the heat of his hand from the bulb, instantly the water rose in the neck more than a palm above its level in the vessel. It is thus that he constructed an instrument for measuring the degrees of heat and cold."

From this it is plain that the instrument consisted merely of a glass tube ending in a bulb, the air in which, being partially expelled by heat, was replaced by water from a glass vessel into which the open end of the tube was plunged. The different degrees of temperature would then be indicated by the expansion or contraction of the air which remained in the bulb; so that the scale would be the reverse of that of the thermometer now in use, for the water would stand at the highest level in the coldest weather.

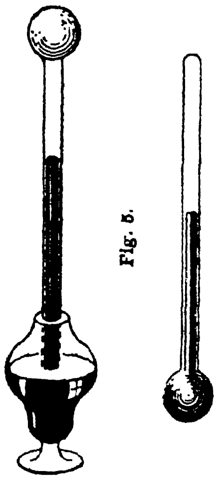


Fig. 5.

AIR THERMOMETER.

So long as the orifice of the tube remained open, this instrument could not be an efficient measurer of temperature, for it was impossible to distinguish the expansive and contractive effects of heat and cold from the effects of varying atmospheric pressure. It was, in truth, a barometer as well as thermometer, although Galileo apparently did not recognise its utility as such.

Galileo's friend, Sagredo, was the first to divide the tube into 100 degrees in 1613. He also appears to have experimented with closed tubes from about 1615; but it was not until many years after (1653) that the practice of hermetically closing the orifice after exhausting the air was introduced. The credit of this capital improvement is due to Leopoldo de Medici, brother of Ferdinando II., who adopted the plan of expelling the air by boiling the spirit and sealing the end of the tube whilst the contained liquid was in an expanded state, thus depriving the instrument of its barometrical character and making it a true thermometer.[1]

We have said above that Galileo's right to this invention was contested, as in the case of his geometrical and military compass, and in others to which we shall come later on. It was claimed for Porta, Santorio, and Paolo Sarpi, in Italy; for Robert Fludd and Francis Bacon in England; and for the Dutchman, Drebbel. But in disproof of these claims it will be enough to say that the first mention of the instrument by Porta occurs in 1606, by Santorio in 1612, by Sarpi and Fludd in 1617, by Bacon in 1620, and by Drebbel in 1621.

In 1604 the attention of astronomers was attracted to a new star which suddenly appeared with great splendour in the constellation Serpen-

[1] About 1611-1612 Galileo substituted spirit of wine for water; and later still Ferdinando II., a former pupil of Galileo, employed coloured spirit of wine, and reduced the dimensions of the tube. Mercury was first used by Lana in 1670. The Fahrenheit scale was adopted in 1724, that of Réaumur in 1730, and the Centigrade scale by Celsius in 1742.

tarius. Maestlin, who was one of the first to notice it, thus describes it:—

"How wonderful is this new star! I am certain that I did not see it before 29th September, nor indeed, on account of several cloudy nights, had I a good view till 6th October. Now that it is on the other side of the sun, instead of surpassing Jupiter as it did, and almost rivalling Venus, it scarcely equals the Cor Leonis, and hardly surpasses Saturn. It continues, however, to shine with the same bright and strongly sparkling light, and changes colour almost every moment, now tawny, then yellow, presently purple, and red, and, when it has risen above the vapours, most frequently white."

Galileo appears to have noticed the new star very soon after Maestlin, *i.e.* on 10th October; and (whether by accident or design is not known) he chose for the subject of his ordinary lectures in the session then opening the theory of the planets. This afforded his auditors the wished-for opportunity of getting his views on the new phenomenon, the appearance of which had given rise to the most bewildering statements. Some said it was a light in the inferior regions of space—"the elementary sphere," but they did not explain how it got there; others, that it was an old star hitherto unnoticed; others again, founding their opinion on abstruse teleological grounds, declared that new stars *were* created by God from time to time, and that this was one of them; while, to add to the confusion, the astrologers deduced from it the wildest forebodings.

After carefully watching the star for some time (it lasted eighteen months), Galileo resolved to expound his views in three extra-ordinary lectures, which were delivered to the public in the great hall (Aula Magna) of the University early in January 1605. In the opening sentences of the first lecture, which are the only parts preserved to us, he took occasion to rebuke his auditors for their general insensibility to the wonders of creation daily exposed to their view, in no way less admirable than the new prodigy, to hear an explanation of which they had hurried in crowds to his lecture room. As regards the star itself we know, from references in his other writings,[1] that he demonstrated that it was neither a meteor, nor yet a body existing from all time, and only now noticed, but a body which had recently appeared and would again vanish. Unlike his contemporaries, Tycho Brahé and Kepler, who thought that new stars (and comets) were temporary conglomerations of a cosmical vapour filling space; or, as is now thought, the result of some catastrophe or collision whereby immense masses of incandescent gases are produced, Galileo suggested that they might be products of terrestrial exhalations of extreme tenuity, at immense distances from the earth, and reflecting the sun's rays—an hypothesis which, as we shall see later on, he also applied to comets. From the absence of parallax he showed that the new star could not be, as the current

[1] "Difesa contro alle Calunnie ed Imposture d Baldassare Capra," and "Postille al Libro d'Antonio Rocco."

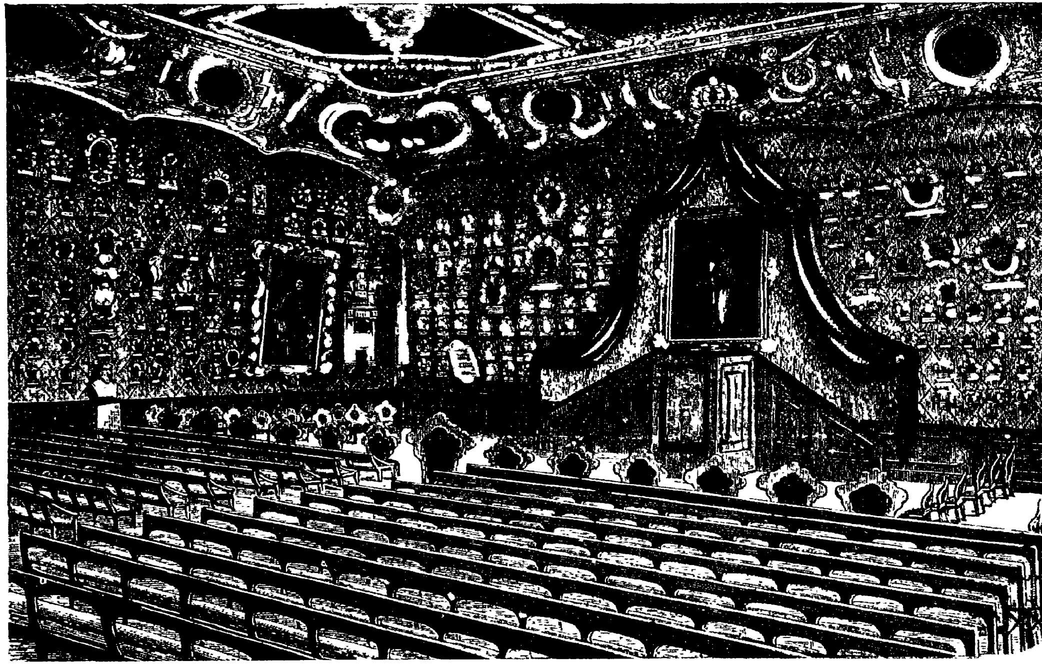
theory held, a mere meteor engendered *in* our atmosphere, and nearer to us than the moon, but that it must be situated among the most remote heavenly bodies.

This was inconceivable to the Aristotelians, whose notions of a perfect and unchangeable heaven, subject neither to growth nor to decay, were quite at variance with the introduction of any such new body. It is hard to say whether Galileo's colleagues, bred in the old philosophy, were more annoyed at the appearance of the star, or at his calling attention to it so publicly and forcibly. Controversy was now unavoidable at Padua, as a few years before at Pisa, and Galileo did not shirk it. He boldly threw down the gauntlet in favour of the Copernican theory, and repudiated the old systems of Aristotle and Ptolemy, which up to that time he had taught in his classes.

The Aristotelians put forth one of their best advocates, Antonio da Montepulciano, to confute Galileo's views, and the latter replied in the only way possible—by ridicule. With the aid of some of his pupils he wrote and printed an exquisite squib in the Paduan dialect, entitled, "Dialogo de Cecco di Ronchitti da Bruzene in Perpuosito del la Stella Nuova."[1]

In 1604, when the second term of Galileo's Professorship expired, he applied for its renewal with a further increase of salary; but, as usual, the Venetian authorities were slow to move. At this

[1] Padua, 1605, edited by Girolamo Spinelli. Reprinted with a modern Italian version in Favaro's edition of Galileo's works, vol. ii. p. 307.



Aula Magna and Lecture Desk, Padua.

[*To face p.* 56.

time Vincenzio Gonzaga, the reigning Duke of Mantua, was anxious to attach him to his court and person, and made some tempting overtures, but nothing came of them. However, while in Florence during the summer of 1605, Galileo took an opportunity of interesting his young pupil Cosimo, son of the Grand Duke, in his case; and at length, and mainly through the influence of the Tuscan Ambassador at Venice (prompted by Cosimo), he was reappointed for a third term of six years, with an augmented salary of 520 florins (about £115), by decree of 5th August 1606.

His public lectures were at this time so thronged that the ordinary class-rooms, large as they were, were often insufficient to contain his audiences. His more popular lectures, as, for instance, those on the new star, were delivered in the Aula Magna, the great hall of the University, and capable of holding 1000 persons. Even this, according to Drinkwater, was not large enough, for "on several occasions he was obliged to adjourn to the open air." [1]

The Cattedra (chair or lecture-desk) which then existed in the Aula Magna, and which Galileo has made historical, is now preserved as a sacred relic in the Stanze di Galileo in the University buildings. It is made of stout rough-planed planks, untrimmed and unpainted, and held together by nails. The Cattedra shown in attached drawing is a modern structure. Around the walls are hung thousands of coats of arms of professors and students of Padua who became distinguished in after life.

[1] "Life of Galileo" (Library of Useful Knowledge), London, 1833, p. 16.

The bust on pedestal shown on the left of the drawing is that of Galileo, by the sculptor Ferrari. It was presented by the Archduke Maximilian of Austria (the ill-starred Emperor of Mexico), and bore on the pedestal an inscription to that effect. After the Austrians were driven out of Italy this inscription was effaced, and replaced by the present one.

## CHAPTER IV

### GALILEO, PROFESSOR IN PADUA—(*continued*)

### 1592–1610

In 1607 Galileo had been studying the "De Magnete"[1] of Dr William Gilbert of Colchester, a book which had for him always a great fascination, and for two reasons—firstly, its arguments traversed many of the principles of the Aristotelian School; and secondly, it contained a number of original experiments in electricity and magnetism, coupled with philosophical reflections of a far-reaching kind, which appealed to his own daring spirit.

Up to Gilbert's time little was known of magnetism. The attractive power of the loadstone was known to Aristotle and Pliny, and the latter appears to have been also acquainted with its power to communicate this attractive property to other bodies.

The polarity of the magnet, that is, its power of taking up a north and south direction when freely suspended, was known to the Chinese from a very early period. Thus, in the second century B.C., we find allusions to "magnetic cars" with

[1] "Physiologia Nova de Magnete, Magneticisque Corporibus," London, 1600. From a letter of Fra Paolo Sarpi, dated 11th September 1602, it would appear that Galileo in that year first became acquainted with Gilbert's book.

which ambassadors from distant countries were provided, in order that they should not miss the way on their return home. In the fourth century of our era Chinese captains employed the magnet to direct their courses across the open seas; and it was through these that the knowledge of the compass was carried to India, and thence to the eastern shores of Arabia and Africa. The Arabic designations *Zoron* and *Aphron* (south and north), which Vincent de Beauvais[1] gives to the ends of the magnetic needle, indicate, like many Arabic names of stars which we still employ, the source whence Western nations received the elements of their scientific knowledge.

The application of the compass to navigation, doubtless, soon led to the discovery of another property of the magnet, its declination or variation from the north pole, according to locality. It must have been known to the Chinese in the twelfth century, as it is mentioned by a Chinese philosopher who wrote about the year 1111. And Columbus made the same discovery on his first voyage to America in September 1492.

The inclination or dip of the needle was noticed, but hardly understood, by George Hartmann in 1544; it was better described by Fortuni Affaytatus in 1549, and by Martin Cortes in 1551; but it only became generally known through the labours of Robert Norman, a nautical instrument maker of Wapping, who began his experiments in 1576, and published an account of them in his "Newe Attractive," 1581.

[1] In his "Speculum Naturale," first published in Paris, 1473.

Doubtless, owing to his other occupations, Galileo's researches in magnetism did not take him far. The main results are given in two letters to Curzio Picchena, Chief Secretary to the Grand Duke of Tuscany, dated 16th November and 9th December 1607. From these we learn that he had made many experiments with loadstones, which resulted in his devising an armature by which the portative force of a stone could be considerably increased. He observed that the longer a stone sustains a weight the more it gains in strength. He also found that smaller stones were usually more powerful than larger ones. Thus, a small stone which he had picked up in Venice was much more powerful than one of 5 lbs. belonging to his friend, Sagredo. This latter could normally sustain a weight of 6½ lbs, but when provided with Galileo's armature it was capable of supporting more than 12 lbs. By breaking up large stones and shaping the pieces in a certain way he was able to make each piece sustain thirty to forty times the weight borne by the original stone. The Abbe Castelli tells us in his treatise on the magnet (*circa* 1639-40):—

"I have seen such a loadstone, only 6 ozs. in weight, armed with iron by the untiring industry of Signor Galileo, and presented to his Highness the Grand Duke Ferdinando, which lifts 15 lbs. of iron worked into the shape of a sepulchre."[1]

[1] This form was probably suggested by the legend of Mohammed's coffin suspended in the air by loadstones. Sir Isaac Newton is said to have had a stone, set in a ring, which weighed only 3 grains, yet was able to support 746 grains. A Galilean stone and armature are now shown in the Tribuna di Galileo in Florence.

Gilbert was one of the first persons who arrived at general, though confused, notions on the subject of gravitation. In his "De Magnete" he explains the influence of the earth upon the moon by comparing the former to a huge loadstone; and in another work, not, however, published until many years after his death,[1] he gives his opinions at greater length. In this treatise he asserts that the earth and the moon act upon each other like two magnets, but the influence of the earth must be greater than that of the moon, on account of its greater mass. Again, although the influence is magnetic in its nature it does not show itself as in ordinary magnets. "It is not," he says, "so as to make the bodies unite like two magnets, but that they may go on in a continuous course." In another place he ascribes the tides partly to the influence of the moon.

These speculations of the English philosopher had a strange fascination for Galileo. In 1608, he had the idea of recording their importance in a medal, which he proposed to strike on the occasion of the marriage of his pupil, Prince Cosimo, and the Archduchess Madeleine of Austria. Under the name, Cosmos, he proposed to engrave the figure of the prince, and a magnet from which depended several pieces of iron, with the mottoes: "Vim Facit Amor," and "Magnus Magnes Cosmos."

In the third "Day" of his Dialogues on the Ptolemaic and Copernican systems, published in

[1] "De Mundo Nostro Sublunari," Amsterdam, 1651. Gilbert died in 1603, aged 63. Leonard Digges and his son, Thomas, Gilbert's contemporaries, held the same view.

1632, he utilises his own early magnetic observations, and warmly acknowledges the merits of Gilbert's work, declaring that his marvellous conception of the earth as a great loadstone was to him a subject of praise, admiration, and envy. The passage is worth quoting:—

"I extremely praise, admire, and envy this author. I think him, moreover, worthy of the greatest praise for the many new and true observations that he has made, to the disgrace of so many vain and fabling authors, who write, not from their own knowledge, but repeat everything they hear from the foolish vulgar, without attempting to satisfy themselves of the same by experiment—perhaps that they may not diminish the size of their books."

Here he is evidently tilting at the "Scientific" writers, numerous in his and the following century, who filled their books with fables about the all-embracing powers and virtues of the magnet, and on which charlatans traded and grew fat. One such person he appears to have met in Venice, of whom he gives an amusing account in the same Dialogues, at the end of the first "Day." One of the speakers, Sagredo, commenting on the remarks of the previous speaker, says:—

"You remind me of one who offered to sell me a secret art, by which, through the attraction of a certain magnetic needle, it would be possible to converse across a space of two or three thousand miles. And I said to him that I would willingly become the purchaser, provided only that I might first make a trial of the art, and that it would be sufficient for the purpose if I were to place myself

in one corner of the room and he in the other. He replied, that in so short a distance the action would be scarcely discernible; whereupon I dismissed the fellow, saying that it was not convenient for me just then to travel into Egypt, or Muscovy, for the purpose of trying the experiment, but that if he chose to go there himself, I would remain in Venice and attend to the rest."

During his residence at Padua Galileo was in the habit of returning to Florence for the long summer holidays. On these occasions for some years, and beginning about 1601, he gave instructions in mathematics to the young prince, Cosimo (born 1590), there being, apparently, no one in Florence whom the Grand Duke thought capable of carrying on this branch of the boy's education. Galileo, of course, was duly sensible of the honour done in thus selecting him as the young prince's mathematical tutor; and the arrangement was desirable for other reasons—it added to his income, always a serious matter; and it gained him the esteem and friendship of the reigning family of Tuscany, which, although not able (as we shall see) to protect him entirely from misfortunes, was still strong enough to make his troubles lighter than they would otherwise have been.

While the Grand Duke was wont to declare that Galileo was the greatest mathematician in all Christendom, his wife, the Grand Duchess Cristina, believed him to be the greatest of astrologers, and at the commencement of what proved to be her husband's last illness, she begged him to correct his horoscope! He did so, and communicated the

result in a letter of 16th January 1609, according to which Ferdinando I. had still many years to live. Galileo's prognostic was speedily proved to be false, as the Grand Duke died twenty-two days after!

Florence, from the earliest period, was noted for its cultivation of the rites of sacrifice and divination, and during the thirteenth and fourteenth centuries, astrology was taught in the Universities of Italy, and in particular at Padua and Bologna. Even in the succeeding three centuries, and in spite of advancing knowledge, judicial astrology still held sway over the hopes and fears, not only of the vulgar, but of the highest and best educated classes.[1]

No wonder, then, if Galileo, *more temporum*, dabbled in horoscopes; but it is not to be supposed that a mind, which early discarded the trammels of ancient sciences, and took nothing on trust or mere authority, could really have believed in them. We prefer to consider his action in this, and other instances, in the light of a pious fraud.[2]

Having brought our account of Galileo's public career up to the eve (1609) of his immortal discoveries

[1] Even grave astronomers and mathematicians were not exceptions. Thus, to mention only a few, Cardan, the algebraist, starved himself to death so that his prognostic as to that event should be fulfilled. Tycho Brahè and Kepler dabbled in the art, and the latter helped to maintain his family by casting nativities and publishing a yearly almanac, the prototype of our modern "Moore." Poor Kepler could not get his salary from the authorities at Prague, and so was driven to astrology, as the only thing that *would* pay, and on it he lived for years. Finally, Francis Bacon and Thomas Browne, typical wise men of England, thought that there was much truth in a sober and well-regulated astrology.

[2] For more on this subject see Favaro's "Galileo Astrologo secondo documenti editi ed inediti," Trieste, 1881; or his "Galileo e Suor Maria Celeste," p. 61.

in astronomy, we must, before proceeding, retrace our steps and give some account of his private life.

We have seen that by the death of his father, in 1591, he had become the head of the family. This position, always attaching a grave responsibility to its possessor, was at this time, and particularly in the present case, fraught with much anxiety. Not only had Galileo, on his slender resources, to keep himself in Padua and provide for the requirements of the household in Florence, but it was his duty to see to his brother's setting out in life, and a still more sacred duty, to find a suitable husband for his unmarried sister, Livia. In Italy in those days, a girl's education being finished, two paths were open —not always for her to choose. One led to the cloister, the other to the house of a husband. It had, apparently, been the family intention for Livia to take the veil, but so great was her aversion to a convent life, that her brother did not insist, much as the arrangement would have saved him in trouble and expense.

Though his sister, Virginia, had been married to Benedetto Landucci before the father's death, the burden of providing the dowry had fallen on Galileo, who, pressed on all sides for money, had been unable immediately to pay the amount. At length, in May 1593, not choosing to wait any longer, and not caring who went short so long as *he* got his due, Landucci threatened to proceed to harsh measures—in fact, to have Galileo arrested for debt the next time he set foot in Florence![1]

[1] "If you come here next month I shall be rejoiced to see you, only you must not come unprovided with funds, for I hear that

Livia writing to her brother, 1st May 1593, shows how all looked to him as to a Father Bountiful :—

"As our Lena[1] is going to join you in Padua I could not help sending by her these few lines to tell you about myself, and, though your lordship may not care to hear about *me*, I care to hear about *you*, for I have no one in the world but you. So please be so kind as to answer, that I may have that little bit of pleasure. Though your lordship writes to our mother, she never brings me your letters—only says, 'Your brother sends his love.' She told me lately your lordship was going to send Michelangelo to Poland. I was at first extremely grieved at hearing this, but then I comforted myself by saying : 'If Galileo thought it was a dangerous place he would not send him,' for I know that you love him dearly. Besides that, I heard you were soon coming here, and it will seem a thousand years till you arrive! Please do remember to bring me some stuff to make a dress, for I am in great need of one."

Galileo had some difficulty in giving his brother a start in life. He had desired for him some post at the Grand Ducal court, but there seemed to be no opening, though his musical talents and elegant manners had gained for him many friends in Florence. Early in 1593 he joined Galileo in Padua, in the hope of obtaining, if not permanent employment as

Benedetto is determined to have his own, and menaces loudly that he will have you arrested the instant you arrive. He is just the man to do it, so I warn you, for it would grieve me much if anything of the kind were to happen."—(Extract from Madam Giulia's letter to Galileo, dated 29th May 1593.)

[1] Nothing is known of this sister. She appears as Elena in the family genealogy, and is supposed by some biographers to have married and settled in Padua. Professor Favaro could find nothing to substantiate this story.

a musician, at least some pupils from amongst the many foreign students of the University. Of the Polish scheme, to which Livia refers in the above letter, nothing is known beyond the fact that Michelangelo did go to Poland, but was soon back again on his brother's hands. At length, early in 1600, the offer of the Polish prince (name unknown)[1] was renewed on very favourable terms, and the young man set out on his second voyage in August of that year, provided with an outfit and money by Galileo. Michelangelo, with his "elegant manners," would evidently be in his element there, for he was to have a place at the prince's table; be dressed like the first gentlemen of his court; have two servants to wait upon him; a coach and four; 200 Hungary ducats yearly (about 300 Italian scudi); and perquisites!

Livia was by this time getting tired of convent life, and was plaguing her mother to find her a husband. Madam Giulia did so, and informed Galileo, upon whom of course would lie the burden of finding the *dot*. Replying on 7th August 1600, he says:—

"From your letter and that of Mr Piero Sali, I hear of the proposed match for our Livia, as to which I do not see how I am to act, for, though from what Mr Piero says, I esteem it desirable, yet it is impossible for me to consent to it just at present. The reason is this [here he enters into details of Michelangelo's Polish engagement, and goes on], I of course must provide him with money, and besides, the prince wishes him to bring certain things; so that what with these articles and what he requires for himself, I cannot avoid spending less

[1] Probably one of the Radziwil family.

than 200 scudi. Now, you know what expenses I have had this last year, so that I really cannot do as I would. On the other hand, Sister Contessa [Superioress of the Convent St Giuliano] writes that on all accounts I ought to take Livia away from the convent, as she hates remaining there. Now, as she has waited so long, I should like her to be well and comfortably settled. If I am to believe Sr. Piero, this Pompeo Baldi [the selected bridegroom] is a good sort of man, yet hearing that, including his private income, he has not 100 ducats yearly, I do not see how a household is to be maintained on that sum. Therefore I would, if possible, have the matter deferred. Michelangelo will, without fail, send me a good sum of money as soon as he gets to his destination, and with this, joined to what I can get together, we may take measures for establishing the child, since she too is determined to come out and partake of the miseries of this world. Meanwhile, I wish you would see about taking her away from St Giuliano and placing her in some other convent till her turn comes, and persuade her that she will lose nothing by waiting. Tell her that there have been queens and great ladies who have not married till they were old enough to be her mother. Therefore, pray see her as soon as you possibly can, and give the enclosed letter to Sister Contessa. She has been asking me to pay what is due for Livia's board. Find out the amount, and I will send it at once."

Depending on his brother's promised help in meeting Livia's dowry, Galileo made up a new match between her and a Pisan gentleman, Taddeo Galletti, on 1st January 1601, promising a *dot* of 1800 ducats, of which 600 ready cash, and a *trousseau* (worth 200), were to be paid down, and the rest to be paid within five years. But of this 800 he

had to borrow 600, relying on his brother's assurances of a speedy remittance from Poland. Vain hopes! Livia had been married nearly a year, and Michelangelo had neither repaid the money advanced for his own outfit, nor contributed to his sister's dowry. Writing to him 20th November 1601, Galileo thus expresses his resentment of such ungrateful conduct:—

"Though you have sent no answer whatever to any of the four letters which I have written within the last ten months, I nevertheless write and repeat what I have said. I would rather think that all my letters had missed you, or any other unlikely thing, than that you meant to be wanting in your duty not only in answering my letters, but in sending money to pay the debts which we owe to various persons, and in particular to Signor Taddeo Galletti, our brother-in-law. If I had imagined things were going to turn out in this manner, I would not have given the child in marriage, or else I would have given her only such a dowry as I was able to pay myself without assistance, since I seem to be fated to bear every burden alone. I beg that you will, without delay, have a deed drawn out and witnessed by a public notary, in which there shall be an acknowledgment of your being bound to pay the said dowry to Signor Taddeo jointly with me. I insist on this being done without delay, and, above all, I desire that you will write and give some news of yourself, for every one is feeling anxious about you, there having been no word of your whereabouts since you left Cracow."

Michelangelo never paid a farthing for years, and then only a small fraction (50 crowns) of what he owed. In 1605 he was back again in Padua,

living at Galileo's expense, till the latter succeeded in getting him a post as music master in the court of the Duke of Bavaria. That he should spend his gains upon himself and, when spent, fall back upon his brother, seemed to him a matter of course. Selfish as he was conceited, never from first to last could he be brought to see that, when he had more than enough for his legitimate expenses, the helping of relations became at once a sacred duty.

For cool effrontery and heartless cynicism the following letter of 4th March 1608, to Galileo, is, we hope, not often paralleled :—

"I was glad to get your letter, and, though it was full of complaints, still I am pleased to find that you do not despise me quite so much as I had imagined. Now I will answer you about the claims of our brothers-in-law. My dear brother, if I have not been able to pay them as I certainly should have liked to do, I do not see that you can blame me so much. You complain of my having spent such a large sum of money on one feast; I do not deny that the sum was large, but just consider that it was on the occasion of my wedding. There were more than eighty persons present, among whom were many gentlemen of importance, and among these there were no less than four ambassadors. Had I not followed the custom of the country, I should have been put to shame, so that I was forced to spend what I did, and indeed could not possibly have managed with less. You cannot accuse me of ever having spent such sums of money simply for my own gratification, never, indeed, have I thrown money away on anything, but, on the contrary, have often denied myself what I wanted in order to save. You say that it does not serve your turn for me to write and tell you that 'God

will not be pleased if you keep up a feeling of rancour against me.' Of course, I know it will not serve your turn; I did not write it supposing that it would help you to get rid of the debt to our two brothers-in-law. As to that matter, I tell you shortly that I will do what I can, and, indeed, will put myself to every inconvenience rather than not satisfy their claims in part; but as to my finding 1400 crowns, which is the sum still remaining to be paid, I know that I cannot do it, and never shall, for I find it scarcely possible to pay the interest. You should have given our sisters a dowry, not merely in conformity with your own ideas of what was right and fitting, but in conformity with the size of my purse. God knows that if I have not paid off my share it is because I could not. When I sent you those 50 crowns, Signor Cosimo lent me 30 of them, and I have not yet repaid him, though I must soon, as he writes saying he wants one of my lutes! By and bye I will borrow another 50 crowns and send you. I cannot promise more, since for these last few months I have been obliged to spend a great deal on my house. I know you will say that I should have waited and thought of our sisters before taking a wife. But, good heavens! the idea of toiling all one's life just to put by a few farthings to give one's sisters! This joke would be indeed too heavy and bitter, for I am more than certain that in thirty years I could not have saved enough to cover this debt. God help me! I would do more if I could. Have a little pity on me and consider; you cannot say that I ever had the heart to gratify my own liking without caring about others. You may say that my having married is a proof that I care not for paying my debts as long as I can gratify my own liking. To this I shall make no answer. God knows I am thankful to have my wife, and I hope

He will enable me to carry out my desire in satisfying this debt. I shall say no more, but I trust you will consider me a good brother, for I will do all I can to send you some assistance, since you say it is all my fault that you are in such distress. But excuse me, if I failed hitherto it was because I could not help it.

"I understand that you are going to send the case of lutes shortly. I have been expecting its arrival with some impatience; for during this Lent I am in great want of them for playing concerted music, and to have them quicker I would not mind paying something more for the carriage."

Galileo must have been more than human not to feel some resentment at the selfishness displayed in this rambling epistle. His anger, however, was short-lived. In 1610, the brothers had again resumed their correspondence, and from that time Michelangelo never failed, as we shall see, to write *whenever* he wanted his brother's assistance. The 50 crowns mentioned in his letter are probably all that he ever paid to his long-suffering brother.

As if the worries and burdens of his father's family were not enough, Galileo must needs add to them the cares of a family of his own. In 1599, he entered into amorous relations with a Venetian lady, Marina Gamba, by whom he had three children, Virginia, born 13th August 1600; Livia, born 18th August 1601; and Vincenzio, born 21st August 1606.

## CHAPTER V

### GALILEO, PROFESSOR IN PADUA—(*continued*)

### 1592–1610

Early in the month of October 1608, the telescope was invented in Holland, and, according to all accounts, its discovery was the result of an accident. Long ago Epicurus defined the universe and all that it contains as the result of a fortuitous concourse of atoms, and so it is very often in the arts and sciences of man, great discoveries are the result of the fortuitous juxtaposition of two and two. In the present case, and as the story goes, an apprentice, playing with spectacle lenses in the shop of one Hans Lipperhey, an optician of Middleburg, noticed that by holding two of them in a certain position a large and inverted view of objects was obtained. On hearing of this the master fixed two glasses in a tube, so that the weather-cock on a neighbouring church spire could be seen apparently nearer and upside down. This toy was shown in his window, where one day the Marquis Spinola chanced to see it, and entered the shop to examine it. Struck by the strange phenomenon it presented, he purchased the instrument, and afterwards gave it to Prince Maurice of


Portrait of Galileo, aged about 40.

[To face p. 74.

Nassau, who thought it might be useful in military reconnaissances.

Among the Acts of the States-General preserved at the Hague, Professor Van Swinden found some interesting papers relating to this matter. On 2nd October 1608 the States Assembly took into consideration a petition of Lipperhey for the exclusive right of making and selling an instrument for seeing at a distance. They suggested that the instrument should be arranged so as to enable one to look through it with both eyes. A trial was fixed for the 4th October, and it was resolved that, if it should be found useful, an engagement should be entered into with the inventor to make three such instruments of rock crystal, and that he should be bound not to divulge the secret to anybody. The trial on the 4th was apparently satisfactory, for two days later the Assembly voted Lipperhey 900 florins. On 15th December they examined his arrangement of the instrument "to see with both eyes," and approved it; but, as others by this time had a knowledge of the invention, they refused to grant him the exclusive privilege of making and selling it. They, however, gave him an order to make, for the use of the Government, two other instruments "to see with both eyes," allowing him the same remuneration as in the first instance.

Of the others referred to above, one was James Metius of Alkmaer, who claimed the invention in a petition, dated 17th October, or fifteen days after Lipperhey. In this petition he declares that the idea occurred to him accidentally

while engaged on other experiments, and that he had now succeeded so far in perfecting his invention "as to make distant objects appear as distinct by it as by the instrument which had lately been offered to the States." Apparently the instrument of Metius was not so good as he said, for he was advised to bring it to greater perfection, when his petition for a privilege would be taken into consideration.

Very soon a third claimant appeared in the person of Zacharias Jansen, also an optician and a near neighbour of Lipperhey. As regards this claim, the truth would seem to be that Jansen, as far back as 1590, had really constructed the microscope; and that, on hearing of Lipperhey's invention, he adapted his own instrument from seeing things near to seeing things at a distance; and so he was able, with some show of reason, to claim the invention.[1]

Leaving this part of the subject, the fact for us at present is that reports of the invention, more or less vague, spread slowly over Europe, and reached our philosopher while on a short visit to Venice about the middle of June 1609. As Galileo's independent invention of the telescope, like so many more of his discoveries, has been denied or belittled by envious detractors in his own and later times, the story had best be told in his own words. In a letter from Venice to his brother-in-law Landucci, dated 29th August 1609, he says:—

[1] For more on this subject see Professor Möll's paper in *Journal, Royal Institution*, vol. i. pp. 319 and 483.

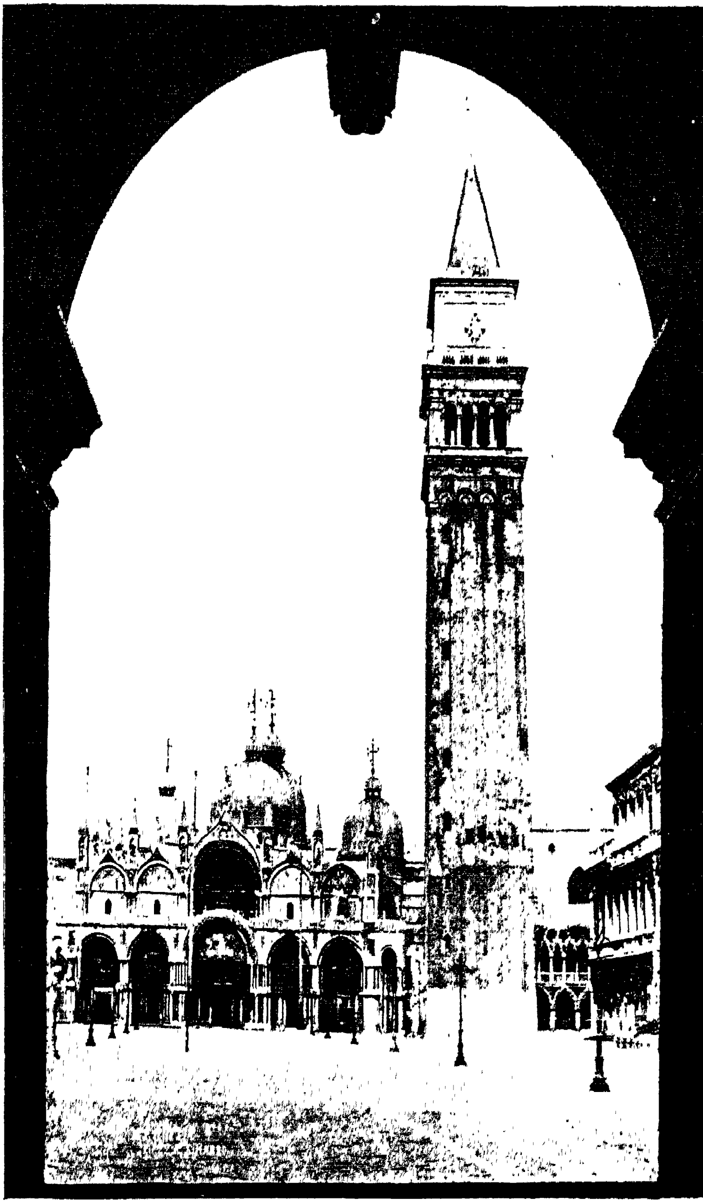
"I write now because I have a piece of news for you, though whether you will be glad or sorry to hear it I cannot say, for I have now no hope of returning to my own country,[1] though the occurrence which has destroyed that hope has had results both useful and honourable. You must know then that about two months ago [*i.e.* about June 1609] a report was spread here that in Flanders a spy-glass had been presented to Prince Maurice, so ingeniously constructed that it made the most distant objects appear quite near, so that a man could be seen quite plainly at a distance of 2 miles. This result seemed to me so extraordinary that it set me thinking, and as it appeared to me that it depended upon the laws of perspective, I reflected on the manner of constructing it, and was at length so entirely successful that I made a spy-glass which far surpasses the report of the Flanders one. As the news had reached Venice that I had made such an instrument, six days ago I was summoned before their Highnesses, the Signoria, and exhibited it to them, to the astonishment of the whole senate. Many of the nobles and senators, although of a great age, mounted more than once to the top of the highest church tower in Venice, in order to see sails and shipping that were so far off that it was two hours before they were seen, without my spy-glass, steering full sail into the harbour; for the effect of my instrument is such that it makes an object 50 miles off appear as large as if it were only five.

"Perceiving of what great utility such an instrument would prove in naval and military operations, and seeing that his Serenity the Doge desired to possess it, I resolved on the 24th

[1] A design which he had formed earlier in the year. See p. 116 *infra*.

inst. to go to the palace and present it as a free gift. On quitting the presence-chamber I was commanded to bide awhile in the hall of the Senate, whereunto the Procurator, Antonio Prioli, one of the heads of the University of Padua, came, and, taking me by the hand, said that the Senate, knowing the way in which I had served it for seventeen years at Padua, and being sensible of my courtesy in making it a present of the spy-glass, had ordered my election (with my good-will) to the Professorship for life, with a salary of 1000 florins yearly; and as there remained yet a year to terminate the period of my last re-election, they willed that the increase of salary should date from that very day.[1] Knowing that Fortune's wings are swift but that those of Hope are drooping [*i.e.* the hope of returning and settling in Florence], I said I was content to abide by his Serenity's pleasure. Then the illustrious Prioli, embracing me, said: 'As I command here and can order what I please (it being my turn this week), I will that after dinner the Senate assemble, and that your election be put to the ballot,' which was done [with few dissentient votes.] So I am bound here for life, and can only hope to enjoy a sight of my own country during the recesses."

[1] The decree is dated 25th August 1609, and the preamble runs as follows:—"Domino Galileo Galilei having been mathematical lecturer in Padua for seventeen years, to the gain of the University and to the satisfaction of all; and having during his professorship made known to the world divers discoveries and inventions to his own renown and the common weal; but in particular having lately invented an instrument by which (knowing the secrets of perspective) things visible, but most distant, are brought within easy vision, and which may be made to serve in many occasions; now, it is proper that this Council do gratefully and munificently recognise the labours of those who are employed for the public benefit. Therefore," etc.



Campanile and Church of San Marco, Venice.

[*To face p.* 78.

In "Il Saggiatore," published in 1623, Galileo enters more fully into the reasonings which led him to the invention, and defends his right to consider the telescope as a child of his brain. He says:—

"What part belongs to me in the invention of the telescope, and why may I reasonably call it my son? As I have long ago shown in my 'Sidereus Nuncius,' news arrived at Venice, where I happened to be at the moment, that a Dutchman had presented to Count Maurice of Nassau a glass by means of which one could see distant things as clearly as if they were near. With this simple fact I returned to Padua, and, reflecting on the problem, I found the solution on the first night after my arrival, and the next day I made an instrument and reported the fact to my friends at Venice, with whom I had been discussing the rumour. In the next six days I made a more perfect instrument, with which I returned to Venice, and showed it for more than a month to the wonder and astonishment of the chiefs of the republic—a task which caused me no small fatigue. But perhaps it may be said that no great credit is due for the making of an instrument, or the solution of a problem, when one is told beforehand that the instrument exists, or that the problem is solvable. It may be said that the certitude of the existence of such a glass aided me, and that without this knowledge I would never have succeeded. To this I reply, the help which the information gave me consisted in exciting my thoughts in a particular direction, and without that, it is possible they may never have been directed that way; but that such information made the act of invention easier to

me I deny, and I say more—to find the solution of a definite problem requires a greater effort of genius than to resolve one not specified; for in the latter case hazard, chance, may play the greater part, while in the former all is the work of the reasoning and intelligent mind. Thus, we are certain that the Dutchman, the first inventor of the telescope, was a simple spectacle-maker, who, handling by chance different forms of glasses, looked, also by chance, through two of them, one convex and the other concave, held at different distances from the eye; saw and noted the unexpected result; and thus found the instrument. On the other hand, I, on the simple information of the effect obtained, discovered the same instrument, not by chance, but by the way of pure reasoning.[1] Here are the steps: the artifice of the instrument depends either on one glass or on several. It cannot depend on one, for that must be either convex, or concave, or plain. The last form neither augments nor diminishes visible objects; the concave diminishes them, the convex increases them, but both show them blurred and indistinct. Passing then to the combination of two glasses, and knowing that glasses with plain surfaces change nothing, I concluded that the effect could not be produced by combining a plain glass with a convex or a concave one; I was thus left with the two other kinds of glasses, and after a few experiments I saw how the effect sought could be produced. Such was the march of my discovery, in which I was not assisted in

[1] This is exactly what Huygens, writing years afterwards, seems to deny. "I would place," he says, "without hesitation above all mortals him who by reflection alone, and without the aid of chance, should arrive at the invention of the telescope." "Dioptrica," Leyden, 1703.

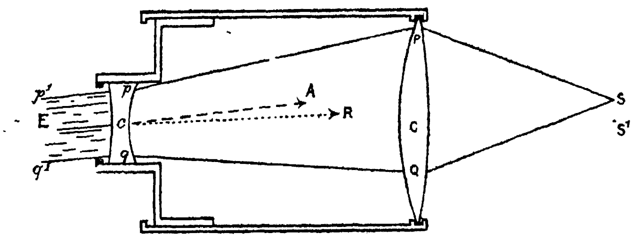
any way by the knowledge that the conclusion at which I aimed was a verity.

"But some people believe that the certainty of the result aimed at affords great help in attaining it. Let them read history, and they will find that Archites made a dove that could fly, and that Archimedes made a mirror that burned objects at great distances, and many other admirable machines. Now, by reasoning on these things such people, doubtless, will be able, with very little trouble and with great honour and advantage, to tell us how they were constructed. And even if they do not succeed, they will be able to certify for their own satisfaction that that ease of fabrication which they had promised themselves from the foreknowledge of the result is very much less than what they had imagined."

Of the first telescope referred to in the above extracts no further mention is made, so we may suppose that it was of little value; but the second, which he presented to the Doge and is unfortunately lost, is mentioned with some particulars in his "Sidereus Nuncius," published at Venice about the middle of March 1610. It consisted of a leaden tube, with a plano-concave eye-glass and a plano-convex object glass, and had a magnifying power of 3 diameters, thus making objects appear three times nearer, and consequently nine times larger. From other sources we learn that the tube was about 70 centimètres long and about 45 millimètres diameter. This instrument was shown for the first time in public on 21st August 1609, from the top of the campanile of San Marco, when the farthest object that could be clearly seen was the campanile of the Church of San Giustina in Padua, distant about 35 kilomètres in a straight line.

The principle of Galileo's telescope is illustrated in the adjoining diagram. C is the centre of the object-glass, and c that of the eye-glass; the former being a convex, the latter a concave lens. The direction of the line cC may be spoken of as the axis of the telescope. It will be readily understood that if the instrument be adjusted so that its axis points in the direction of a minute object s′, then, on applying the eye to the eye-glass, that object appears exactly in the centre of the field of view.

Fig. 6.




THE GALILEAN TELESCOPE.[1]

The eye placed at E will see the point s′ in the same direction as if the two intervening lenses were suddenly annihilated. To fully realise the phenomenon of vision through the telescope, we must examine the course of the rays of light which reach the eye from an object slightly removed from the axis of the telescope. Such an object is represented by S in the figure. Rays of light emanate from this point in all directions; we are concerned, however, only with those which strike the object-glass between P and Q. These rays pass through both lenses, being refracted each time. The convex

[1] For convenience in drawing the breadth of the telescope is enlarged out of proportion to its length.

lens bends them inwards, so that they would all, if subsequently uninterrupted, very nearly meet at about the point F in the figure. But before reaching this point they are intercepted by concave lens, which turns their course outwards again. The final result will, provided the distance cC between the two lenses be suitably adjusted, be a beam of parallel rays, as indicated in the figure. To a beam of parallel (or, it may be, very slightly divergent) rays the human eye is sensible; so that the beam of rays represented by pp′, qq′, and the space between them, would on entering the eye render visible the small luminous object S from which they originally came. And as the apparent direction of this object depends entirely on the direction in which the rays were last travelling before entering the eye, the object S will be seen in the direction of the broken line EA, the dotted line ER being inserted to show the direction in which the same object would have been visible but for the intervention of the telescope. The effect of this is that the apparent distance of S and s′ from one another is increased about three times by the use of the instrument, which we may accordingly say has a magnifying power of 3 diameters.

In the diagram the objects examined, S and s′, have for obvious reasons been placed near the convex lens. But if the telescope be directed to two stars, near one another in the heavens, but both of course at practically infinite distances from the observer, the phenomena are exactly as described above, although the concave lens would require to be pushed slightly into the main tube in order that

the rays of light from the stars, after passing down the telescope, may finally emerge parallel. At the same time, the change of distance of an object observed will slightly affect the magnifying power.

On his return to Padua Galileo made his third telescope, of which he only says that "it made objects appear more than sixty times larger," which is equivalent to a magnifying power of about 8 diameters. But in a very few days he had a much better one, which enlarged four hundred times. With this he made his first observations on the moon, which he "brought to a distance of less than 3 semi-diameters of the earth, thus making it appear about twenty times nearer and four hundred times larger than when seen by the unaided eye." He also turned it towards Jupiter, but with no specified results. To obviate the shaking when held in the hand, the instrument was firmly fixed on a support. The lenses were adjustable, the tubes which held them being capable of being drawn out of, or pushed into, the main tube. Thus, to see clearly things not very distant, the glasses should be drawn apart a little; while for very distant objects they had to be approached. He found he could grind large convex lenses more truly than small ones. He preferred therefore to make his object-glasses larger than necessary, and to cover a portion of their surface, leaving open around the centre just so large a space as he found, on testing, to give the best results.

While on a short visit to Florence, probably in October 1609, he had this instrument with him, and showed it to his late pupil, Cosimo II., now

become Grand Duke, "who, to his great surprise and delight, was able to see that the moon was a body very similar to the earth."

Very early in January 1610, Galileo had constructed a fifth and still more powerful telescope, "sparing neither labour nor expense," which showed objects more than thirty times nearer and nearly one thousand times larger.[1] With this instrument he not only verified and completed his observations on the moon, begun the previous autumn with his fourth telescope, but he also discovered Jupiter's moons, some of the fixed stars, and contributed to the solution of that long-standing puzzle to philosophers—the Milky Way.

Writing to Belisario Vinta, then with the Tuscan Court at Pisa, 30th January 1610, Galileo thus modestly alludes to his first series of discoveries:—

"I am at present staying in Venice for the purpose of getting printed some observations which I have made on the celestial bodies by means of my spy-glass (*mio occhiale*) and which infinitely amaze me. Therefore do I give thanks to God, who has been pleased to make me the first observer of marvellous things unrevealed to bygone ages. I had already ascertained that the moon was a body very similar to the earth, and had shown

[1] Galileo arrived at the powers of his glasses by the following crude method. "Place," he says, "upon a wall at a certain distance two unequal discs, one of which you will observe with the telescope and the other with the naked eye. If the disc seen through the telescope appear equal to the other, the magnifying power of the instrument is in the proportion of the two discs. If they do not appear equal the 'other' disc must be enlarged or diminished until they do, and then the magnifying power will be, as before, in the proportion of the discs."

our Serene Master, the Grand Duke, as much, but imperfectly, not then having such an excellent spy-glass as I now possess, which, besides showing the moon most clearly, has revealed to me a multitude of fixed stars never before seen, being more than ten times the number of those that can be seen by the unaided eye. Moreover, I have ascertained what has always been a matter of controversy among philosophers, namely, the nature of the Milky Way. But the greatest marvel of all is the discovery of four new planets. I have observed their motions proper to themselves and in relation to each other, and wherein they differ from the motions of the other planets. These new bodies move round another very great star, in the same way as Mercury and Venus, and, peradventure, the other known planets, move round the sun. As soon as my tract is printed, which I intend sending as an advertisement to all philosophers and mathematicians, I shall send a copy to his Highness, the Grand Duke, together with an excellent spy-glass, which will enable him to judge for himself of the truth of these novelties."

The tract referred to in the above letter is his "Sidereus Nuncius" (Messenger of the Stars), the preface of which is dated 4th March 1610, and the book, doubtless, appeared immediately after, say, towards the middle of March. In this epoch-marking treatise he gives the results of his observations to date, of which we proceed to give a *résumé*.

His observations were first directed to the moon. The discovery of new spots on its face, added to those already visible to the naked eye, and observations on the changes of light on those spots, led him

to the conclusion that the surface of the moon, far from being smooth and polished, according to the opinion of the ancients, was rough with deep depressions and high mountains. Those parts which remained or became brilliant he inferred were land, like the solid parts of this earth, while those which remained obscure — the permanent spots — were water. The illuminated edges of the moon in all its phases showed themselves perfectly round, without those indentations which one would expect from the inequalities of its surface. Galileo explained this appearance—(1) by supposing that the mountainous parts, as it were, masked each other, so that at the distance of the earth the intervening depressions were not discernible, and (2) by the existence of a lunar atmosphere of a density such as to reflect the solar rays while not obstructing the vision. Thus the reflection of solar light by this atmosphere gave the appearance of a regular circular contour, only intensified in the parts most illuminated. From the appearance of illuminated mountain-tops in the dark part of the moon at some little distance from the broken line along which sunrise or sunset was general, he was able to judge of the height of some of these mountains. And his calculation agrees very well with the modern estimate. The higher mountains were found to rise 4 or 5 miles above the general level—a height which is seldom exceeded on the earth.

He, of course, remarked the feeble light, so-called phosphorescent, which, in the first and last quarters of the moon, makes visible to us that part of its disc which is no longer illuminated directly by

the sun. After showing that this light did not originate in the moon itself, and was not reflected there from Venus, he concludes that it can only be due to the sunlight reflected from the earth to the moon, and thence reflected back to our eyes.[1]

After referring for greater details to the work which he proposed to publish on the system of the world, he contends, contrary to the received opinion, that our earth *is* a moving planet, and that it exceeds the moon in luminosity, and, therefore, that it is far from being the sink of impurity hitherto supposed.

In examining the fixed stars and comparing them with the planets, Galileo discovered a remarkable difference. While the planets showed themselves as discs like little moons, the stars appeared no larger than they do to the naked eye, bright specks in the firmament, sending forth twinkling rays. In explanation of this fact he supposes that the telescope has the effect of stripping the star of the false light by which it is surrounded when viewed with the naked eye. This spurious corona is ascribed by him to the effect of irradiation which generally increases with the brightness of the field upon which the luminous object is projected. Thus, at sunset, when the obscurity of the heavens is tempered by the twilight, the stars, even of the first magnitude, appear very minute. So, with respect to Venus, notwithstanding her usual splendour, she does not

[1] Leonardo da Vinci and Maestlin had already arrived at the same conclusion ; but da Vinci's writings were certainly not known to Galileo (see p. 23 *ante*), and Maestlin's opinion probably not, as knowledge in those days did not spread fast, except in special cases.

exceed a star of the sixth magnitude on those occasions when she happens to be visible at noon.[1]

Upon directing his telescope to the more conspicuous star-clusters, he was astonished to find that they contained, besides those already known, a great number of other stars too faint to be individually recognised by the naked eye. The number of the Pleiades, which had been fixed at seven, now rose to forty, while in the constellation of Orion, instead of seven he counted eighty stars. Certain portions of the Milky Way were resolved into a countless number of minute stars; and he inferred that as a whole it derived its singular whiteness from innumerable other stars which his instrument was not powerful enough to separate.

When Galileo turned his *fourth* telescope to the planets, he saw them as little moons. Jupiter's disc was of considerable magnitude, but in no other way did he differ from the other planets. Now, on 7th January 1610, directing his *fifth* and more powerful glass towards Jupiter, his attention was at once drawn to three small but very bright stars that appeared in his vicinity, two on the east side and one on the west. He at first imagined them to be fixed stars, and yet there was something in their appearance which he thought curious. They were all disposed in a right line parallel to the plane of the ecliptic, and were brighter than other stars of the same magnitude.[2] This did not, however, induce

[1] He has a great deal more on this subject of irradiation in his letters to Griemberger on Lunar Mountains; in his work on "Sun-Spots," and "Il Saggiatore."

[2] See attached facsimile of Galileo's notes of these observations.

him to alter his opinion that they were fixed stars, and therefore he did not note their distances from each other or from the planet. Happening, by mere accident, as he says, to examine Jupiter again on 8th January, he was surprised to find that the stars were now arranged quite differently. They were all on the west side, and were nearer to each other than on the previous evening, and at equal distances apart. The strange fact of the mutual approach of these stars had as yet no significance for him; it only excited his astonishment that the planet should be seen to the east of them all when on the previous night it was to the west of two of them. He very soon began to think that perhaps the motion of Jupiter might be *direct*, contrary to the accepted opinion of astronomers, and that he had got in advance of the stars. He therefore waited for the following night with some anxiety, but he was disappointed, for the heavens were enveloped in clouds. On 10th January he could see only two stars, and they were both on the east side! He suspected that the third might be concealed behind the disc of the planet. Those visible appeared as before in the same right line, and lay in the direction of the ecliptic. Unable to account for such changes by the motion of the planet, and being at the same time fully assured that he always observed the same stars, his doubts now turned into admiration, and he concluded that the motions must be referred to the stars themselves and not to the planet. He therefore determined to watch them with the closest attention.

On 11th January he again saw only two stars,

Adi 7. di Gennaio 1610 Giove si vedeva col cannone con 3. stelle fisse così * ⊛ * delle quali senza il cannone niuna si vedeva. a dì 8. appariva così ⊛ * * * era dunque diretto et nõ retrogrado come pongono i calculatori.

Adi 9. si nugolò. a di 10. si vedeva così * * ⊛ ciò è cõgiũto cõ la più occidẽtale sì che la occultava per quãto si può credere.

Adi 11. era in questa guisa * * ⊛ et la stella più vicina à Giove era la metà minore dell'altra, et vicinissima all'altra dove che le altre sere erano le dette stelle apparite tutte tre di equal grandezza et tra di loro egualm. lontane; dal che appare intorno à Giove esser 3. altre stelle erranti invisibili ad ogn'uno sino à questo tẽpo.

Adi 12. si vedde in tale costituzione * ⊛ *. era la stella occidentale poco minor della orientale, et giove era in mezzo lontano da l'una et dall'altra quãto il suo diametro ĩ circa: et forse era una terza picolissima et vicinissima à ♃ verso oriẽte; anzi pur vi era veramẽte havẽdo io cõ più diligẽza osservato, et essẽdo più imbrunita la notte.

Adi 13. havẽdo benissimo fermato lo strum.to si veddono vicinissime à Giove 4. stelle in questa costituzione * ⊛ * * * ò meglio così * ⊛ * * * e tutte apparivano della med.ma grandezza, lo spazio delle 3. occidẽtali nõ era maggiore del diametro di ♃. et erano fra di loro notabilm. più vicine che le altre sere; ne erano in linea retta esquisitam. come per avãti ma la media delle 3 occidẽtali era ũ poco elevata, ò vero la più occidẽtale alquãto depressa; sono queste stelle tutte molto lucide bẽchè picolissime et altre fisse si appariscono della med.ma grandezza nõ sono così splendẽti.

Adi 14 fu nugolo. Adi 15. era così ⊛ * * * *. la pross.a à ♃. era la minore et le altre di mano ĩ mano maggiori: gl'interstitii tra ♃ et le 3. seguẽti erano tutti quãto il diametro di ♃. ma la 4.a era distante dalla 3.a il doppio ĩ circa; nõ facevano ĩteram. linea retta, mà come mostra l'esempio, erano al solito lucidiss. bẽ che picole, et nõ scintillavano come anco per avanti

♃.
♃ long. 71.38 lat. 1.13 Me: 2.30
1.13
1.17

Facsimile Sketches of Jupiter's Satellites (from Galileo's MSS.).

[To face p. 90.

still on the east side of Jupiter, but the outer one was now nearly twice as large as the other, although on the previous night they were almost equal. This fact, taken in connection with the constant change of the relative positions of the stars and the total disappearance of one of them, left no doubt on his mind of their real character. He concluded that there are in the heavens three stars revolving round Jupiter in the same way as Venus and Mercury revolve round the sun. On 12th January he again saw three stars, two on the east side of Jupiter, and one on the west. The third began to appear about three o'clock in the morning, emerging from the eastern limb of the planet; it was then very small, and discernible only with great difficulty. On 13th January he saw four stars, three of them on the west side and one on the east. They were all in a line parallel to the ecliptic, with the exception of the central one of the western group, which was a little towards the north. They were all about the same size, and shone with a much greater lustre than fixed stars of the same magnitude. January 14th was cloudy, but next night he saw all four stars to the west of the planet, all nearly in the same right line, and increasing in size and brilliancy, according to their distance from Jupiter.

And so he continued nightly, up to 2nd March 1610, to make these observations, sixty-six of which are figured and described in the "Sidereus Nuncius."

The persistence of the relative distances between

these four bodies and Jupiter in all their changes left no room for doubt that they accomplished with him, and in about twelve years, a revolution around the sun as a centre. Their own orbits round the planet were unequal in time, those nearest moving more rapidly than those more remote; while the most remote of all appeared to complete its revolution in one-half month.[1]

"It is now," he says in conclusion, "not simply a case of one body (the moon) revolving around another body (the earth), while the two together make a revolution around the sun, as the Copernican doctrine teaches; but we have the case of four bodies or moons revolving round the planet Jupiter, as the moon does round the earth, while they all with Jupiter perform a grand revolution round the sun in a dozen years."

By the 1st of January 1610 Galileo had fitted up his workshop, so as to be able to make and grind his own glasses, of which he turned out large numbers, but of which only a small percentage was found to be of any great value. Thus, by the middle of March, out of one hundred and more which he had ground "at great fatigue and expense," only ten were able

[1] Two years later, in the opening passages of his "Discourse on Floating Bodies," he gives the periods of revolution approximately as follows:—The innermost one, 1 day 18 hours 30 minutes; the second, 3 days 13 hours 20 minutes; the third, 7 days 4 hours; and the fourth or outermost, 16 days 18 hours. The modern figures are in days, hours, minutes, and seconds, 1, 18, 28, 36; 3, 13, 17, 54; 7, 3, 59, 36; and 16, 18, 5, 7, respectively. A fifth satellite was discovered in 1892, whose period is only 11 hours and 57½ seconds. Jupiter's belts were discovered by Torricelli, a disciple of Galileo.

to show the newly discovered moons of Jupiter and the fixed stars.[1] The object glasses gave him the most trouble, as it is easy to understand, since everything depends on the degree of accuracy with which this glass brings to a focus the rays of light passing through it.

The same difficulty was found elsewhere, for Kepler, in one of his letters about this time, tells Galileo that it was easy to find good concave lenses in Germany, but that he found it most difficult to procure decent convex ones. In fact, for a long time no instruments at all approaching Galileo's were to be had in Europe, and he was consequently besieged with orders from all parts. Thus, Daniel Antonini, writing from Brussels in April 1611, complains that in all Flanders no instrument was to be had capable of magnifying more than five times, and says that he was obliged to make one himself, which was able to show "fairly well the inequalities of the moon's surface and the Medicean stars."[2] As late as 1634 a good instrument could not be procured in Paris, Venice, or Amsterdam; and even in Holland, the home of the telescope, down to 1637, there was not one which could show Jupiter's disc well defined.[3]

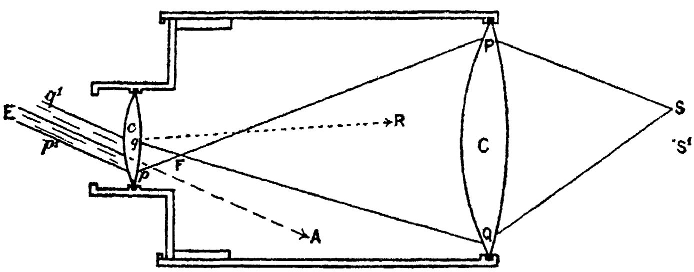
[1] Letter to Vinta, 19th March 1610. At this time his clever workman Mazzoleni was also engaged not only on the geometrical and military compass, of which many hundreds were made and sold all over Europe, but on hydrostatic balances, air thermometers, magnets and magnetic compasses for ships, and various kinds of drawing compasses for engineers and architects. He had also added a printing-press, where his tract on the Geometrical and Military Compass was set up. See pp. 43-44 *ante*.

[2] *I.e.* Jupiter's satellites, see p. 96 *infra*.

[3] Galileo continued all these years to grind his own glasses, and it was not until his eyesight began to fail that he consented to

It detracts little from the merit of Galileo's invention that the modern refracting telescope is based upon a different combination of lenses than that which he used. After possessing himself of one of Galileo's instruments, Kepler designed, though he did not make, a telescope consisting of two convex lenses. The difference between the two systems can be seen by comparing the adjoining diagram with that of Galileo's telescope already

Fig. 7.




KEPLERIAN TELESCOPE.[1]

given. Without entering into a detailed description, it may be well to point out that in Galileo's the rays of light which travel from the point S and penetrate to the observer's eye do not, on striking the object-glass, cover the whole of its surface;

impart his secret to Ippolito Mariani, commonly known as Il Tordo, whom he appointed as his successor in the art. From about 1637, Francesco Fontana of Naples also began to turn out good glasses of the Galilean pattern. After Galileo's death Torricelli, having devised an improved way of grinding and polishing lenses, of which he was the first to calculate previously the curve, made some instruments of great perfection. Gradually other Italians took up the art, and became noted for the excellence of their telescopes, as Viviani, Severino, and Campani.

[1] For convenience in drawing the breadth of the telescope is enlarged out of proportion to its length.

and also that (as explained above) these rays, passing down the tube of the telescope, are not allowed to come to a focus, but are intercepted by the eye-glass. In these respects Kepler's system is different; and for work at the present day, although the interval of nearly three centuries has produced refinements and complications in the manufacture undreamt of by either Galileo or Kepler, the modern instrument is essentially a development of the combination devised by Kepler. Galileo's arrangement is suitable for low magnifying powers, and has advantages where portability is desired; it survives in the common field-glass and opera-glass.

It must further be pointed out before forming an estimate of Galileo's work that he knew nothing of the reflecting telescope. Finding, as he did, that a convex-lens as object-glass brought the rays of light from a distant object to—or, more truly in his case, *towards*—a focus, it seems not to have occurred to him that a concave mirror might serve the same purpose. The first reflector was designed by James Gregory, a Scotch mathematician, in 1663, and described in his "Optica Promota"; but poverty prevented its construction. It was nine years later that Sir Isaac Newton, acting on Gregory's suggestions, and influenced also by the results of his own researches in the theory of light produced the first reflecting telescope, now preserved in the rooms of the Royal Society, London. At the present day only a comparatively small number of the world's great telescopes are constructed on the reflective system. But for certain

departments of astronomical work these have advantages over the refractor.[1]

During the Easter recess in Padua, April 1610, Galileo, according to custom, would probably have visited Florence; but this time he had an express invitation from the Court, then at Pisa, to repair thither for the purpose of explaining to the Grand Duke his discovery of the four satellites of Jupiter, which, in honour of the reigning family of Tuscany, he proposed to call Medicean Stars, after the four brothers Cosimo II., Francesco, Carlo, and Lorenzo de Medici. Cosimo II., who all his life showed a sincere attachment to his old tutor, asked for and obtained the gift of the instrument with which this discovery was made;[1] but Galileo quickly repented of his generosity. He evidently could not part with his "old discoverer," as he affectionately called it in after years; so, while always reserving it for the Grand Duke, he kept it near himself till his death, when it was handed over to Prince Leopoldo, brother of Ferdinando II.

Of its subsequent history little for certain is known. It would appear that in Galileo's last years the instrument was accidentally broken. Then, in 1675, there is a record in the inventory of the effects of Cardinal Leopoldo de Medici of a "broken object-glass with which Galileo discovered the four new planets"; and in 1677 another record of its having been set in an ivory frame, for which

[1] For much interesting information on the subject of telescopes, see Grant's "History of Physical Astronomy," London, 1852, chap. xx., and article "Telescope," in "Encycl. Brit.," 9th ed.

[1] Cosimo made him a return present, in the form of a gold chain and medal, as a badge of merit, worth about 400 scudi (£85).

one Vittorio Crosterr, an engraver and carver, was paid 19½ lire. It is now preserved (together with two telescopes, said to have been made by Galileo, and certainly of his time) in the Tribuna di Galileo in Florence, with many other precious relics of the period. Accurate measurements of it have been quite recently made by Professor Roiti of the University of Florence, as follows:—Focal distance, 1.70 mètres; diameter .056 mètre. One face has the curvature of a sphere with radius of .935 mètre, and the other face is practically plane, having just a trace of convexity.

# CHAPTER VI

## GALILEO, PROFESSOR IN PADUA—(*concluded*)

### 1592-1610

THE hundred and more telescopes, which Galileo had made in the first half of 1610, were distributed with copies of the "Sidereus Nuncius" amongst the princes and learned men of Italy, France, Flanders, and Germany. The best instruments he reserved for particular friends and patrons, amongst whom he mentions the Duke of Bavaria, the Elector of Cologne, Cardinal del Monte, and the Duke of Urbino, as having "begged" for them. The Cardinal sent in return a small picture to which an indulgence was attached! The Duke of Bavaria was not behind-hand, but what his present was is not stated (let us hope it was more substantial than the Cardinal's); while the Elector of Cologne wrote that the pamphlet was disappointingly incomplete, since it contained no directions for the making of the instrument. He therefore requested Galileo to impart the secret, promising to recompense him in a princely fashion.

In communicating this request, and evidently not caring to bear the brunt of the Elector's anger

in case of non-compliance, Galileo's brother, Michelangelo, wrote, 14th April 1610:—

"See if you can gratify the Elector by showing him how to make the instrument, and if not, write to him direct in your own way."

Then he peevishly continues:—

"You say not a word about the telescope *I* asked you for. If I am not a prince, able to remunerate you, at least I am your brother, and it seems very strange to me that you do not care to gratify me."

At the French Court the arrival of Galileo's telescope caused immense excitement, the queen, Marie de Medici, being particularly interested in it as the invention of a distinguished fellow-countryman. It is related that in her eagerness to see the moon through it, she would not wait till the instrument was suitably fixed at the open window, but fell on her knees on the floor, to the consternation of her suite and the amazement of the grave Italian in charge of the telescope.

The solicitude of the French Court to gain a place in the heavens by the side of the Medici family is very amusing. In a letter of 20th April 1610, the great astronomer is begged:—

"In case you discover any other fine star, call it by the name of the Great Star of France, as well as the most brilliant of all the earth, and, if it seems fit to you, call it rather by his proper name, Henri, than by the family name Bourbon. Thus you will have an opportunity of doing a thing due and proper in itself, and, at the same time,

of rendering yourself and your family rich and powerful for ever."[1]

As the news of Galileo's marvellous discoveries spread over Italy, the popular excitement grew intense. Thus, in Florence, poets chanted the discoveries and the glory of their fellow-citizen, and a public *fête* was celebrated in his honour. In Venice, Girolamo Sirturo describes the excitement as amounting to frenzy, and tells an amusing story of his own experience. With the first telescope which he had succeeded in making, he ascended the tower of San Marco, in the hope of trying it unmolested. Unluckily for him, he was seen by some idlers in the square below, a crowd soon collected round him, who insisted on taking possession of the instrument, and, handing it one to another, detained him for hours till their curiosity was satisfied. Desirous of obtaining the same gratification for their friends, they endeavoured to find out where Sirturo lodged, but he, overhearing their enquiries, thought it better to quit Venice early the next morning and pursue his observations in a less inquisitive neighbourhood.

In the "Sidereus Nuncius" Galileo did not formally proclaim his discoveries in relation to, and in support of, the Copernican theory of the world; but in his lectures and conversations he made no secret of his belief. Nor, indeed, was any specific announcement needed; his readers could see for themselves the connection, and the speedy result was a tremendous explosion of incredulity and malice. The Aristotelians were furious, and

[1] Henry IV. was assassinated very soon after, on 14th May 1610.

even men like Welser of Augsburg, and Clavio of Rome, both admirers of Galileo, would not credit his statements until they had learnt better from observations of their own. The latter, who was the first mathematician of his day, for months, down to October 1610, "laughed at the idea of there being four new planets, to see which they must first be put inside the telescope. Let Galileo keep his opinions and welcome. I hold to mine." Nor did it mend matters when Galileo offered 10,000 scudi to any one who would construct so cunning an instrument. Others refused even to look through the telescope; some, lest they should see, others convinced they could not see, things of which Aristotle had made no mention!

Among other sticklers for conservatism were the celebrated professors, Cesare Cremonino of Padua, one of Galileo's colleagues, and Julius Libri of Pisa, both of whom peremptorily rejected, on *a priori* grounds, Galileo's discoveries and the conclusions he drew from them. Libri died in December 1610, refusing to look through a telescope, and stigmatising to the last the "absurdities" of the presumptuous Florentine. In communicating the news of Libri's death to his friend Welser (17th December), Galileo expressed the hope that this stiff-necked opponent of his "absurdities," who would not look at them from earth, might now perhaps see them on his way to heaven.

Some passages of Galileo's letter to Kepler of 19th August 1610 will best show how these men of science refused to be convinced.

"You are the first and almost the only person, who, after a cursory investigation, has given entire credit to my statements. . . . We will not trouble ourselves about the abuse of the multitude, for against Jupiter even giants, to say nothing of pigmies, fight in vain. Let Jupiter stand in the heavens and let the sycophants bark at him as they will. . . . In Pisa, Florence, Bologna, Venice and Padua, many have seen the planets, but all are silent on the subject and undecided; for the greater number recognise neither Jupiter nor Mars, and scarcely the moon, as a planet . . . What is to be done? Shall we side with Democritus or Heraclitus? I think, my Kepler, we will laugh at the extraordinary stupidity of the multitude. What do you say of the leading philosophers here to whom I have offered a thousand times of my own accord to show my studies, but who, with the lazy obstinacy of a serpent who has eaten his fill, have never consented to look at the planets, or moon, or telescope? Verily, just as serpents close their ears, so do men close their eyes to the light of truth. To such people philosophy is a kind of book, like the Æneid or the Odyssey, where the truth is to be sought, not in the universe or in nature, but (I use their own words) by comparing texts! How you would laugh if you heard what things the first philosopher of the faculty at Pisa brought against me in the presence of the Grand Duke. He tried hard with logical arguments, as if with magical incantations, to tear down and argue the new planets out of heaven! [1]

As a specimen of the "logical" arguments to which Galileo alludes in the above extract, this is

[1] Ponsard in his drama "Galilée," Paris, 1867, takes off capitally these proud Aristotelians (Act I. Scenes 3 and 4); but in the process Galileo's history is mostly turned upside down.

what Francesco Sizzi, a Florentine astronomer, says in his "Dianoia Astronomica" (Venice, 1611.)

"There are seven windows given to animals in the domicile of the head, through which the air is admitted to the tabernacle of the body, to enlighten, to warm, and to nourish it. What are these parts of the *microcosmos?* Two nostrils, two eyes, two ears, and a mouth. So in the heavens, as in a *macrocosmos*, there are two favourable stars, two unpropitious, two luminaries, and Mercury undecided and indifferent. From this and many other similarities in nature, such as the seven metals, etc., which it were tedious to enumerate, we gather that the number of planets is necessarily seven. Moreover, these satellites of Jupiter are invisible to the naked eye, and therefore can exercise no influence on the earth, and therefore would be useless, and therefore do not exist. Besides, the Jews and other ancient nations, as well as modern Europeans, have adopted the division of the week into seven days, and have named them after the seven planets. Now, if we increase the number of the planets, this whole and beautiful system falls to the ground."[1]

Another opponent deserves to be named, if only for the impudence of the charge he brings against Galileo.

"We are not to believe," says Christmann, in his "Nodus Gordius," "that nature has given Jupiter four satellites in order to immortalise the name of the Medici. These are the dreams

[1] Sizzi would not look through the telescope, because he was sure beforehand he could not see any of the marvels which Galileo pretended to find in the heavens by its aid. In 1618 he was broken on the wheel in Paris for some political crimes.

of idle men who love ludicrous ideas better than our laborious maintenance of the heavens. Nature abhors such horrible chaos, and to the truly wise such vanity is detestable."

In the midst of all this opposition and abuse, we must not suppose that Galileo was without friends, and even some converts. Thus, on 7th May 1610, he was able to inform Secretary Vinta that even the most exalted persons in Padua, who had vehemently attacked him, had at length given up the game, and had acknowledged, *coram publico*, that they were not only convinced, but were ready to defend him against all comers.

The praises of Kepler, then renowned as the first astronomer in Europe, were, as we have just seen, a great consolation to him. Kepler had the "Sidereus Nuncius" at once reprinted in Prague, with a long and appreciative preface from himself, and some laudatory verses from Thomas Seggett, a learned Scotchman, a former pupil of Galileo, then working with him.[1] In the preface, which is in the form of a letter to Galileo, dated 19th April 1610, Kepler says:—

"I was sitting idle at home thinking of you, most excellent Galileo, and of your letters, when the news was brought me of the discovery of four planets by the help of the double eye-glass. . . . The authority of Galileo had the greatest influence on me, earned by the accuracy of his judgment, and by the excellence of his

[1] The oft-quoted exclamation, *Galilaee! vicisti!* is always wrongly attributed to Kepler. It occurs in Seggett's verses.

understanding. So I immediately fell to thinking how there could be any addition to the number of the planets without upsetting my 'Mysterium Cosmographicum," published thirteen years ago, and according to which Euclid's five regular solids do not allow more than six planets round the sun. I am, however, so far from disbelieving the existence of the four circumjovial planets, that I long for a telescope to anticipate you, if possible, in discovering two round Mars (as the proportion seems to require), six or eight round Saturn, and, perhaps, one each round Venus and Mercury." [1]

Galileo's detractors must have been hard pushed for a stick wherewith to strike him when they took Kepler's preface to be a covert attack. Certainly Maestlin, Kepler's old master, took it so, and wrote:—

"In your essay you have plucked Galileo's feathers well—I mean you have shown him not to be the inventor of the telescope, not to be the first to observe the irregularities of the moon's surface, not to be the first discoverer of more worlds than the ancients were acquainted with, etc. One source of exultation was still left him, but from the apprehension of that Martin Horky has now entirely delivered me."

[1] This is a specimen of the wild notions in which Kepler revelled. For the same curious reason Huygens, who in 1659 discovered a satellite near Saturn, declared that no more would be found, since the one near Saturn, Jupiter's four, and the earth's one, made up the number six, exactly the number of the planets, thus together making twelve, which is the first perfect number! In Galileo's day Scheiner thought he saw five satellites round Jupiter, de Rheita counted nine, and others gave him a round dozen! Jupiter is now known to have five, Saturn eight, besides his rings, Uranus four, Ne tune one, and Mars two.

It is difficult to see where in Kepler's preface Maestlin found all this, for it is one continued encomium. Maestlin, however, was not the only one to misunderstand. The Martin Horky just mentioned, a young German travelling in Italy, wrote to Kepler:—

"I will never concede his four new planets to that Italian from Padua, though I die for it."

He followed up this declaration by publishing a book, which is evidently the one referred to by Maestlin.[1] It professes to examine four main questions touching the alleged planets — (1) Whether they exist? (2) What are they? (3) What are they like? (4) Why they are? Horky summarily disposes of the first question by declaring that he had examined the heavens with Galileo's own glass, and could see no such thing as a satellite about Jupiter. As to the second he declares solemnly that he does not more surely know that he has a soul in his body, than that reflected rays are the sole cause of Galileo's observations. In regard to the third question he says, rather illogically, that these planets are like the smallest fly compared with an elephant; and as

[1] "Peregrinatio contra Nuncium Sidereum." Galileo, by the advice of Kepler, did not deign to reply, but he found able champions in his Scotch friend and pupil, John Wedderburn of Padua (p. 51), and in Antonio Roffeni, a professor in the University of Bologna. Apparently, our old acquaintance, Professor Magini, was the secret instigator of this outrage, but, openly, he pretended to be very shocked at Horky's bad manners. The latter, however, afterwards confessed to Kepler that Magini and other professors in Bologna were the real offenders. Sizzi had admitted the same inspiration in the case of his "Dianoia Astronomica," of which we have already spoken.

to the fourth he concludes that the only use of them is to gratify Galileo's vanity and thirst of gold. Horky sent a copy of this amazing production to Kepler, and, returning to Prague soon after, presented himself to the great astronomer. But the reception was little to his taste, for the burst of indignation which followed showed him Kepler's real sentiments. The conclusion is characteristic. After venting his wrath against "this scum of a fellow, whose obscurity had given him audacity," Kepler, recounting the story to Galileo, says:—

"In the end, Horky begged so hard to be forgiven that I have taken him again into favour upon this one condition, to which he has agreed—that I am to show him Jupiter's satellites, and that he is to see them, and own they are there."[1]

After completing his observations on Jupiter, Galileo turned his glass to the other planets to see if they, perchance, had attendant moons; but up to 25th June 1610, he was unable, with all his diligence, to discover any. At this he was inclined to be a little glad and a little sorry—glad because he would thus be the only one destined by God for

[1] See Kepler's letter to Galileo, dated 25th October 1610. As usual, Galileo's right to the first discovery of Jupiter's satellites was contested, the claimant being Simon Mayer of Anspach, whom we have met before in connection with the Capra plagiary (p. 45 *ante*). In 1614 he published at Nuremberg his "Mundus Jovialis," in which he formulates his claims. As to these, it is enough to say with Humboldt that Kepler, who knew Mayer personally, makes no mention of his discovery either in the edition of the "Sidereus Nuncius" which he published in Prague in April 1610, or in his letters to Galileo, or in those addressed to the Emperor, Rudolph II., in the autumn of 1610. On the contrary, Kepler always spoke of "the glorious discovery of the Medicean stars by Galileo." See "Cosmos," vol. ii. p. 703.

so great a discovery; and sorry because he could not oblige the French Court by finding Henri Quatre a place in the heavens. However, before a month elapsed, he made another brilliant discovery—the ring of Saturn; only it did not appear to him as a ring, but like a triple star, of which the central one (Saturn itself) was three to four times larger than the laterals, and all three in a plane parallel to the equinoctial points or ecliptic. Not wishing to make public the discovery until he had made further observations in the autumn, when Saturn would be well above the horizon, and yet fearing that some one might forestall him, he announced the discovery in a brief letter, dated Padua, 30th July 1610, to Belisario Vinta at Florence, but begged him to keep it secret for a while. As a further precaution he sent to friends in Italy and Germany a jumble of thirty-seven letters as follows:—

SMAISMRMILMEPOETALEUMIBVNENUGTTAVIRAS

Kepler and other friends puzzled long over this string of letters, the former thinking it had some reference to his favourite planet Mars. At length Giuliano de Medici, Tuscan ambassador at the German Court, was charged by the Emperor Rudolph II. to ask for the solution, to whom Galileo, replying 13th November 1610, gave the following startling explanation:—

"Altissimum Planetam Tergeminum Observavi."

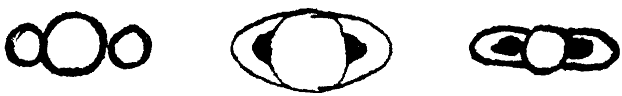
"I have observed," he goes on to say, "with great admiration that Saturn is not a single star

but three together, which, as it were, touch each other. They have no relative motion, and are constituted in this form (see Fig. 8, A), the middle being much larger than the lateral ones. If we examine them with a glass of inferior power, the three stars do not appear very

Fig. 8.

(*Facsimiles from Galileo's MSS.*).

(A) (B) (C)



distinctly. Saturn has an oblong appearance somewhat like an olive, but by employing a glass which multiplies the superficies *more* than 1000 times, the three globes will be seen very distinctly and almost touching, with only a small dark space between them.[1]

"I have already discovered a court for Jupiter, and now there are two attendants for this old man, who aid his steps and never leave his side."

The learned world of Italy had not yet had time to digest the surprising facts announced in

[1] The telescope with which Galileo discovered Jupiter's satellites had, as we have seen, a power of 30, enlarging objects "*nearly* 1000 times." Here, and in other letters of the latter half of 1610, he speaks of his glass enlarging "*more* than 1000 times," but without specifying the power, as in all previous cases. From this, Professor Favaro concludes that between April and July Galileo had made for himself a sixth telescope. This may be so, but I think it more likely that he only improved his fifth, his "old discoverer" (for instance, by substituting a better eye-glass), thereby increasing its enlarging power from *nearly* 1000 to *more* than 1000. Indeed, in his letter to Clavio of 17th September 1610, he says as much — "Having ultimately improved my instrument a little more." Galileo never got beyond this power.

the "Sidereus Nuncius," when the asserted triple nature of Saturn again contravened the prevailing ideas that, by order of Aristotle, there was nothing new to be found in the heavens. Accordingly, the peripatetics were inclined to discredit the discovery; the most they would admit was that Saturn *appeared* to be of an oblong shape—precisely as Galileo *said* it appeared when viewed through glasses of less power than his own.

Continuing his observations, Galileo found that the lateral bodies did not retain the same apparent magnitudes. In fact, they had been gradually diminishing, although they appeared to be immovable, both with respect to each other and to the central body. They continued to grow less and less during the next two years, and towards the close of 1612 they vanished altogether! Horrified at this extraordinary phenomenon, and full of alarm for the consequences to himself when his Aristotelian opponents should come to hear of it, he thus wrote to Welser on 1st December 1612:—

"Looking at Saturn within these last few days, I found it solitary without its accustomed stars, and, in short, perfectly round and defined like Jupiter, and such it still remains! Now what can be said of so strange a metamorphosis? Are, perhaps, the two smaller stars consumed like spots on the sun? Have they suddenly vanished and fled? Or has Saturn devoured his own children? Or was the appearance, indeed, fraud and illusion, with which the glasses have for so long mocked me and many others who have observed with me? Now, perhaps, the time is come to revive

the withering hopes of those who, guided by more profound contemplation, have fathomed all the fallacies of the new observations, and recognised their impossibility. I cannot resolve what to say in a change so strange, so new, so unexpected. The shortness of time, the unexampled occurrence, the weakness of my intellect, the terror of being mistaken, have greatly confounded me."[1]

However, he soon plucked up courage, and in the same letter conjectured that the two attendant stars would reappear after revolving round the planet, and that by the summer solstice of 1615, they would not only be again visible, but be more luminous, and larger.

Commenting on the above quoted passage, Arago[2] and other modern writers after him conclude that Galileo was so discouraged by the disappearance of the lateral bodies that he made no further observations on Saturn. But Arago is most certainly wrong here. Galileo continued to observe Saturn for many years. By the middle of 1613, he was able to inform his friends that, according to his prediction, the lateral stars were reappearing!

Apparently, no change calling for special comment was noticeable until the summer of 1616,

[1] The real reason is now well known. The ring lies in the plane of Saturn's equator, and we obtain a view of its north or south side according as the planet at different parts of his orbit leans his north pole towards or away from the earth. Accordingly the ring goes through all its phases once during the twenty-eight years of Saturn's revolution round the sun; disappearing twice in that period, at the time when the planet is so placed that he presents the ring edgeways to our line of vision.

[2] "Astronomie Populaire," Paris, 1857, vol. iv. p. 442.

when he announced a new fact relating to Saturn, which filled his friends with admiration and pleasure. For considerably more than two hundred years this new fact remained not only unexplained, but forgotten. Then Albèri, while preparing his edition of Galileo's Works, 1842-56, found amongst his MSS. a paper containing some calculations belonging to the year 1616, on the back of which was a pen-and-ink sketch, as shown in Fig. 8, *b*). No explanation of the figure was to be found, but Albèri concluded that it was intended to show the form of Saturn's ring as seen by Galileo in August 1616, and as communicated to his friends, as above stated.

Not satisfied with the evidence that the sketch found by Albèri was really made by Galileo, and that it belonged to the date assigned, Professor Favaro has lately instituted a new search, and with the happiest results. Taking as his starting-point a letter from Prince Cesi to Galileo of 3rd September 1616, acknowledging the "new fact" about Saturn,[1] Favaro has been rewarded by finding the *ipsissima verba* of Galileo. They were sent by Prince Cesi to John Faber in Rome for his information, and by him immediately passed on, as the latest piece of news, to Cardinal Federigo Borromeo, amongst whose papers, now in the Ambrosian Library, Milan, Favaro found them. Quite recently the learned Professor has read a paper on this interesting discovery, from which I quote Galileo's words as follows:—

[1] Unfortunately, the year 1616 is one of those in which Galileo's correspondence, as it has come down to us, is incomplete.

"I cannot rest without signifying to your Excellency [Prince Cesi] a new and most strange phenomenon observed by me in the last few days in Saturn. Its two companions are no longer two small and perfectly round globes, as they have hitherto appeared to be, but are now bodies much larger, and of a form no longer round, but, as shown in the annexed figure (see Fig. 8, c), with the two middle parts obscured, that is to say, two very dark triangular-like spaces in the middle of the figure and contiguous to the middle of Saturn's globe, which latter is seen, as always, perfectly round."[1]

Towards the end of his life, when Galileo was blind, and a confirmed invalid from age and ailments, he once more referred to Saturn. Castelli, writing to him from Rome under date 4th August 1640, said :—

"The other evening, on turning the telescope towards Saturn, I noticed, to my great amazement, that he was a single star, distinct and round, and with two other round stars (one at each side) lying in the direction from *Levante* to *Ponente* [*i.e.* nearly east and west], and no longer in the form of coifs attached to the central body, such as your first observations showed them."

Replying on 28th August 1640, Galileo wrote :—

"When first I observed Saturn he was composed of three round stars, situated in a straight line from *Ponente* to *Levante*, of which the central was much larger than the lateral ones. Thus I continued to see him for some months.

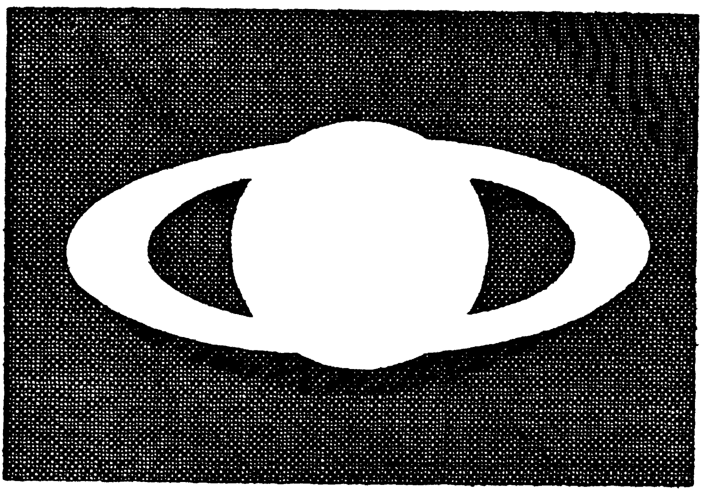
[1] *Atti del Reale Istituto Veneto*, February, 1901.

Then, after an interval of some more months, I again examined him and found him solitary, *i.e.* the great central star was only to be seen. Amazed at this result, and supposing it to be due to some kind of change, I ventured to say that in five or six months, *i.e.* at the summer solstice, the two small lateral stars would reappear. They did, and so I saw them for a long time after. Then after another interval, during which Saturn was masked by the sun's rays, I again observed him, and now saw him with two mitres, instead of round stars, which gave him the figure of an olive. I saw the central globe very distinctly, and two very dark spots in the middle of the attachment of the mitres, or, as one may say, the ears. So I observed him for many years; and now your Rev. writes (as also other of my friends) that the mitres are transformed into two small globes. It may be that in the last three years, during which I have been unable to make any observations,[1] Saturn may have become once again solitary, and then later on may have returned to the form in which I at first observed him. It will be for the future and for others to make observations, registering the times of mutation so as to accurately determine their periods — that is, if there will be any persons curious enough to do what I, from the same motive (not knowing how to do better), have done for so long a time."

Thus we see that up to the last, Galileo had made no announcement as to the precise nature of Saturn's appendage. He contented himself with describing what he saw, and, recognising the incompleteness of his knowledge, and, perhaps,

[1] Galileo became totally blind in December 1637.

the inadequate power of his glasses, he left it to the future and to others to solve the problem. This was done by Christian Huygens in 1656. Working with a refracting telescope with a magnifying power of 100 diameters, this celebrated astronomer not only saw and described the ring as a ring, but discovered one of Saturn's satellites, of which eight are now known to exist.



SATURN'S RING AS SEEN BY HUYGENS.

# CHAPTER VII

## GALILEO QUITS PADUA AND RETURNS TO FLORENCE

### 1610-1612

GALILEO'S fame, especially through his telescopic discoveries, and partly also through the exertions of his noisy opponents, had long extended beyond the bounds of Italy. The eyes of all Europe were directed to the great astronomer of Padua, and students flocked to him from all quarters. According to a familiar French proverb, one must suffer in order to be beautiful, so, to be a professor with a European reputation demands some sacrifice, entails some evil, which, under certain circumstances, may outweigh the good. It was so in Galileo's case; lectures and private lessons of all kinds left him little leisure for his own studies, and so, after twenty years' professorship at Pisa and Padua, he began to wish for a post in which he could devote himself entirely to the completion of various works on mechanics and astronomy, for which, during all these years, he had been amassing materials. A letter from Padua in the spring of 1609, shows his longing for this salaried leisure. It is not addressed, but from the context it must have been written to some one

high in influence, if not in office, at the Court of Florence, probably to Belisario Vinta, the Grand Duke's chief Secretary of State.[1] This first attempt, however, had no definite result, so that a few months later (after the invention of the telescope) he gratefully accepted, as we saw, the Chair of Mathematics at Padua for life. But the invention of the telescope and his consequent discoveries had now given him a world-wide reputation, and it appeared desirable to the Tuscan Court to attach to itself so great a man.

The first steps towards this end were taken when Galileo visited Pisa, about Easter 1610, in order to show to Cosimo II. his telescopic discoveries, and especially the satellites of Jupiter, which bore his family name of Medici. Galileo's case is fully stated in his letter of 7th May 1610, to Vinta, as follows :—

"I will not hesitate to say, having now laboured during twenty years, and those the best of my life, in dealing out (as one may say) in detail, and at the request of everybody, the little talent which God has given me, that my wish is to have sufficient leisure to enable me, before my life comes to a close, to conclude three great works which I have in hand, and which may, perhaps, bring some credit to me and to those who assist me in the undertaking, besides being a greater service to students than in the rest of my life I could do them by personal tuition. Greater leisure than I have here I doubt if I could get elsewhere, so long as I am obliged to give public and private lectures in order to meet the expenses of my family.

[1] We do not reproduce it, as its substance is given in a later and fuller communication quoted *infra*.

Nevertheless, not even the liberty I have here is sufficient, when I am obliged to spend many and often the best hours of the day at the call of this and that man. My salary is 520 florins, which I am almost certain will be advanced to as many crowns upon my re-election, and this I can increase, by receiving pupils and by private lessons, to any extent I please. My public duties do not occupy me more than sixty half-hours in the year, and even then not so strictly but that I may, on occasion of any pressing matter, contrive to get some vacant days. The rest of the time is absolutely at my own disposal; but as my private lectures and domestic pupils take up very much of this spare time, to the hindrance of my own studies, I wish to be entirely exempt from public duties, and in a great measure from the others. Therefore, if I am to return to my native country, I should wish that leisure and opportunity be afforded me to complete my works without employing myself in lecturing. In short, I wish to gain my bread by my writings, which I would always dedicate to my Serene Master.

"Of useful and curious secrets I possess so many that their very abundance does me harm, for if I had but one I should esteem it greatly, and, perhaps, through it I might have found that fortune which as yet I have not met. And, indeed, I have not sought it. *Magna longeque admirabilia apud me habeo.* Many are no good to me, or I should say, they are only of use to princes; for they alone make wars, build fortresses, and, for their royal pleasure, spend such sums of money as private gentlemen cannot, any more than I can.

"The works which I have to finish are chiefly —(1) two books on the system or structure of the Universe, an immense work, full of philosophy,

astronomy, and geometry; (2) three books on local motion, a science entirely new, no one, ancient or modern, having discovered any of the many admirable consequences which I demonstrate in natural and violent motions, so that I may with reason call it a new science invented by me from its very first principles; (3) three books on mechanics, two on the demonstration of principles, and one of problems. Although others have treated this subject, no one either in quantity or quality has done a quarter of what I am writing on it. I have also treatises on natural and other subjects, such as (1) on sound and speech; (2) on light and colours; (3) on the tides; (4) on the composition of continuous quantity; (5) on the movements of animals; and others. I have also an idea of writing some books relating to the military art, giving not only a model of what a soldier ought to be, but teaching him with exact rules everything in the way of mathematics that it is his duty to know, as castrametation, manœuvring battalions, fortifications, sieges, surveying, estimation of distances, knowledge of artillery, uses of various instruments, etc.

"I also wish to reprint the 'Use of the Geometrical and Military Compass,' which is dedicated to his Highness, and is no longer to be procured. This instrument has met with such favour from the public that no others of the kind are now made, and I know that up to this several thousands of mine have been made and sold.

"Then I need not say what an amount of labour will be required to fix the periods of the four new planets, a task the more laborious the more one thinks of it, as they are separated from one another by very brief intervals, and are all very similar in size and colour. So that, illustrious Signor, I must begin to think in what way I can

free myself from those employments which so retard my own studies—particularly those, which another might fill quite as well as I can. Therefore, I beg you to bring these considerations to the notice of his Highness, and acquaint me with his decision.

"As to salary, I shall be quite content with the sum you named to me at Pisa, feeling it an honour to be his Highness's servant. I say nothing as to the amount, being convinced that as I am to live upon it his Highness would not wish to deprive me of any of those comforts which others enjoy, who are less in want of them than I am. Therefore I say no more on this point.

"Finally, as to the title and pretext by which I take service, I would wish that to the title of Mathematician his Highness would be pleased to add that of Philosopher, as I have studied a greater number of years in philosophy than months in pure mathematics. And how far I have profited by it, and if I can and ought to merit the title, I hope to be able to show his Highness as often as it is his pleasure to give me an opportunity of discussing such subjects with those whose knowledge is most esteemed." [1]

[1] Some of the treatises named in this letter, like the one on dialling previously mentioned, and, it is feared, more of Galileo's papers and correspondence, are now lost, partly through the accidents of his stormy life, and in transport from place to place, and partly, as we shall see later on, through the extraordinary negligence and criminality of custodians. The loss of the essay on Continuous Quantity is particularly to be regretted, as it would be interesting to see how far he succeeded in methodising his thoughts on this important subject. It is to his early disciple Buonaventura Cavalieri (who refused to publish his book so long as he hoped to see Galileo's printed) that we owe "The Method of Indivisibles," which is recognised as one of the first germs of Newton's Fluxional Calculus. The treatises on sound and speech and on light and colours were probably never completed, but we find fragments of them in later works, as "Il Saggiatore" and the Dialogues of 1632 and 1638. Similarly, of the movements of animals we have the fragment "Intorno al camminare del cavallo."

This letter brought the business to a speedy settlement. On 5th June, Vinta wrote that Cosimo II. was pleased to nominate him as First Mathematician of the University of Pisa, with a yearly salary of 1000 scudi, and without the obligation of residing at Pisa, or of delivering lectures. In reply, Galileo declared himself entirely satisfied with the proposed conditions, but added that he would like to be designated not only First Mathematician at Pisa, but also Philosopher and Mathematician to the Grand Duke himself. Accordingly, on 12th July 1610, the decree summoning him to Florence in this twofold capacity was issued.

Notwithstanding the many advantages which this new post secured to him, it was a bad exchange from the free soil of Republican Venice to the protection (ineffectual as it proved at the crisis of his life) of a princely house which, although personally well disposed towards him, could never shield him as could and would the Republic. About 1542, the Jesuits had established a school in Padua, and, increasing gradually in influence, had shown symptoms of a design to get the management of public education entirely into their own hands. After several violent disputes, it was at length decreed by the Venetian Senate, in 1591, that no Jesuit should be allowed to give instruction at Padua in any of the sciences taught in the University. As years dragged on, the relations between Rome and Venice became increasingly strained, until at last, in April 1606, Pope Paul V. took the extreme step of placing the

contumacious Republic under an interdict. The Senate's reply was to expel for ever the Jesuits from the soil of Venice.[1] Since this event, full liberty of thought and teaching was enjoyed in the Republic; whereas, in religious Tuscany, Church influences were very strong and weighed heavily in all matters, and particularly in politics and science.

Early in September 1610, Galileo left Padua, where, eighteen years before, he had found a ready welcome and an ever-increasing appreciation, deserting his staunch friends Paolo Sarpi, Francesco Sagredo, and many others. Indeed, he seems to have felt himself that he was not behaving well in this matter, for, in his letter to Vinta last quoted, he begged that the negotiations be kept secret until all was decided and therefore irrevocable.[2]

Although he was received in Florence with much honour, soon the clouds of envy, malice, and bigotry, began to form round him, and ultimately, as we shall see, combined, if not to his destruction, at least to embitter the rest of his life. Sagredo foresaw this clearly. On his return from the East in the spring of 1611, he wrote expressing his regret and disappointment at not finding Galileo, and his grave doubts as to the wisdom of the change.

[1] Their nocturnal deportation from the city of lagoons is amusingly told in Galileo's letter of 11th May 1606, to his brother Michelangelo.

[2] Galileo tried to induce Kepler to apply for his chair in Padua, but without success. Again in 1617, on the death of Magini, Kepler was offered the vacant chair in Bologna, which he once more refused. See Martin's "Galilée," Paris, 1868, pp. 14 and 194; and for Kepler's reasons, Drinkwater's "Life of Kepler," in Library of Useful Knowledge, p. 38.

"Where," he asks, "will you find the same liberty as in Venetian territory, and, notwithstanding all the good qualities of the young ruler of Tuscany, who can promise with any confidence that, if not ruined, you will not be persecuted and tossed on the surging billows of Court life by the raging storms of envy?"

Within less than a month after his arrival in Florence, Galileo made another astounding discovery in the heavens — namely, the varying crescent form of the planet Venus. He announced this discovery to his correspondent, Giuliano de Medici at Prague, in an anagram, as in the case of his observations on Saturn, as follows:—

"*Haec immatura a me iam frustra leguntur o y,*"

and after convincing himself, by three months' observations, of its correctness, he sent the following solution of the riddle on 1st January 1611.

"*Cynthiae figuras aemulatur mater amorum.*"

"That is, Venus rivals the appearances of the moon; for Venus being now arrived at that part of her orbit in which she is between the earth and the sun, and with only a part of her enlightened surface turned towards us, the telescope shows her in a crescent form, like the moon in a similar position."

Tracing her through the visible portion of her orbit, Galileo had the satisfaction of seeing the illuminated part assume successively the forms appropriate to his hypothesis. It was with reason, therefore, that he laid stress on the importance of this observation, which established yet another

fact obnoxious to the Aristotelians, namely, that a new point of resemblance was here found between the moon and one of the principal planets; for, as it was well known that the moon was luminous only when exposed to the sun's rays, so this change of figure in Venus demonstrated that she, and, therefore, probably all the other planets, were of themselves not luminous, but only reflected the sunlight which fell upon them. And thence he concluded that they must all revolve round the sun—"a fact which was surmised by Pythagoras, Copernicus, Kepler, and their disciples, but which could not be proved by ocular demonstration, as it now can be in the case of Venus and Mercury. Kepler and the other Copernicans may now be proud to have judged and philosophised correctly, and it may well excite disgust that they were regarded by the generality of men of book-learning as having little understanding and as not much better than fools."

It had always been a formidable objection to the Copernican theory that Venus and Mercury did not exhibit the same phases as the Moon, which they should do if they revolved round the sun. Copernicus himself had endeavoured to account for this, by supposing that the sun's rays passed freely through the body of the planets, and Galileo took occasion to praise him for not being deterred from adopting the system (which on the whole appeared to agree best with the phenomena) by meeting with some appearances which it did not enable him to explain.

Another objection, equally embarrassing to the

Ptolemaic and Copernican systems, was raised. Why, it was asked, did not Venus appear four times as large when nearest to the earth as when farthest away? Galileo was now able to answer this also. Venus does not appear four times as large when she is nearest to the earth, simply because her illuminated part is not then four times as large, though her diameter is; and as with the naked eye we judge of her size only by the amount of light, the nearer distance is offset by the lesser light, so that her size does not seem to vary.[1]

Milton, whose *Paradise Lost* has many allusions to Galileo and his astronomy, has not suffered this brilliant discovery to pass unnoticed. After describing the creation of the sun he adds:—

> "Hither, as to their fountain other stars
> Repairing, in their golden urns draw light,
> And hence the morning planet gilds her horns."[2]

Of changes in Mars Galileo could say little for certain. After observing him carefully for four months he was seen to vary in size according to his distance from the sun. Galileo thought that when the planet was at the middle points of his orbit he observed changes in the illuminated disc something like the phases of the Moon and Venus; but it is difficult, he adds, with so small an object to say whether it is always perfectly round.

[1] The revolution of Mercury about the Sun which Galileo here infers, was confirmed as a fact by Kepler's observation of the transit of Mercury in 1630. Our countryman, Horrox, was the first to observe a transit of Venus in 1639.

[2] Book VII. v. 364. For other references, see Book I. v. 286; III. 565 *et seq.*, 722 *et seq.*; IV. 589; V. 261, 414; VII. 577; VIII. 1-178.

fact obnoxious to the Aristotelians, namely, that a new point of resemblance was here found between the moon and one of the principal planets; for, as it was well known that the moon was luminous only when exposed to the sun's rays, so this change of figure in Venus demonstrated that she, and, therefore, probably all the other planets, were of themselves not luminous, but only reflected the sunlight which fell upon them. And thence he concluded that they must all revolve round the sun — "a fact which was surmised by Pythagoras, Copernicus, Kepler, and their disciples, but which could not be proved by ocular demonstration, as it now can be in the case of Venus and Mercury. Kepler and the other Copernicans may now be proud to have judged and philosophised correctly, and it may well excite disgust that they were regarded by the generality of men of book-learning as having little understanding and as not much better than fools."

It had always been a formidable objection to the Copernican theory that Venus and Mercury did not exhibit the same phases as the Moon, which they should do if they revolved round the sun. Copernicus himself had endeavoured to account for this, by supposing that the sun's rays passed freely through the body of the planets, and Galileo took occasion to praise him for not being deterred from adopting the system (which on the whole appeared to agree best with the phenomena) by meeting with some appearances which it did not enable him to explain.

Another objection, equally embarrassing to the

Ptolemaic and Copernican systems, was raised. Why, it was asked, did not Venus appear four times as large when nearest to the earth as when farthest away? Galileo was now able to answer this also. Venus does not appear four times as large when she is nearest to the earth, simply because her illuminated part is not then four times as large, though her diameter is; and as with the naked eye we judge of her size only by the amount of light, the nearer distance is offset by the lesser light, so that her size does not seem to vary.[1]

Milton, whose *Paradise Lost* has many allusions to Galileo and his astronomy, has not suffered this brilliant discovery to pass unnoticed. After describing the creation of the sun he adds:—

> "Hither, as to their fountain other stars
> Repairing, in their golden urns draw light,
> And hence the morning planet gilds her horns."[2]

Of changes in Mars Galileo could say little for certain. After observing him carefully for four months he was seen to vary in size according to his distance from the sun. Galileo thought that when the planet was at the middle points of his orbit he observed changes in the illuminated disc something like the phases of the Moon and Venus; but it is difficult, he adds, with so small an object to say whether it is always perfectly round.

[1] The revolution of Mercury about the Sun which Galileo here infers, was confirmed as a fact by Kepler's observation of the transit of Mercury in 1630. Our countryman, Horrox, was the first to observe a transit of Venus in 1639.

[2] Book VII. v. 364. For other references, see Book I. v. 286; III. 565 *et seq.*, 722 *et seq.*; IV. 589; V. 261, 414; VII. 577; VIII. 1-178.

Of Mercury he also observed little, because that planet's orbit does not take him far from the sun, and, in consequence, his small disc is always so resplendent that not even the best telescope could deprive him of his factitious rays (irradiation).[1]

In consideration of the intense interest, friendly and otherwise, excited by these epoch-making discoveries, and the probability of their being used against him in Rome, Galileo thought it desirable to go there himself, and acquaint at first hand the *savants* and dignitaries of the Church with his work in the heavens. These people, he argued, must be first made to see the facts with their own eyes, so that they may be able to comprehend and assent to the conclusions to be drawn from them. Therefore, on 15th January 1611, he wrote to Vinta (who was then with the Court at Pisa), informing him of his design, adducing the above reasons, and requesting the necessary leave of absence. His request was not only granted but the Grand Duke placed a litter at his disposal, undertook to defray all expenses, and directed the Tuscan Ambassador in Rome to lodge him at the Embassy and to entertain him during the visit. Illness, however, supervened, so that it was not till 23rd March 1611, that he was able to set out, provided with many letters of introduction, amongst them one from Michelangelo the younger (nephew of the

[1] For Galileo's observations on Venus, Mercury, and Mars, see his letters to Castelli, dated 30th December 1610, and to Clavio in Rome under the same date.

great sculptor and painter) to Cardinal Barberini (afterwards Pope Urban VIII.).

He was received with the greatest distinction by princes and all the Church dignitaries, who vied with learned laymen in doing him honour. Even those who discredited his discoveries and dreaded their results, were as eager as the true friends of science to see and hear this wonder of the age. His first duty was to call on his old friends, Cardinal del Monte and the Jesuit Father Clavio, by the latter of whom he was presented to the leading Jesuits of the Roman College.

After exhibiting on several occasions in the garden of the Quirinal Palace, belonging to Cardinal Bandini, all his recent discoveries, or "celestial novelties" as they were called, a commission of four scientific members of the Roman College was appointed, at the request of Cardinal Bellarmine, to examine and report. As the result, the commissioners, Fathers Clavio, Griemberger, Maelcote, and Lembo, were constrained to admit what they had long denied and ridiculed, being now convinced by ocular proofs of the truth of the facts announced by Galileo. By this opinion (given on 24th April) of the Papal experts, his discoveries received to a certain extent the sanction of the Church. Attentions of all sorts were now heaped upon him; Pope Paul V. granted him a long audience, and assured him of his unalterable good-will, which, however, did not remain so, as the sequel will show. High dignitaries of the Church followed suit, and were lavish in their admiration;

and the Accademia dei Lincei (founded in 1603 by Prince Cesi), the prototype of our Royal Society, elected him a member. So that when he took his departure, on the 4th of June, Galileo left behind in Rome many sincere friends and admirers, and some very envious foes.

A letter of 31st May, from Cardinal del Monte to Cosimo II., will best show how Galileo's friends regarded his visit.

"Galileo has, during his stay in Rome, given great satisfaction, and I think he must have felt it no less himself, for he had the opportunity of showing his discoveries so well, that to all clever and learned men here they seemed no less true and well-founded than astonishing. Were we still living under the ancient republic of Rome I verily believe there would have been a column on the Capitol erected in his honour."

Immediately after the publication of the report of the Bellarmine Commission, Galileo announced a new discovery in the heavens, namely, dark spots on the body of the sun, which, towards the end of April 1611, he showed to several prelates and *savants* in Rome.

Describing these phenomena at a later date[1] Galileo states that at first he was undecided whether to explain the ever-changing nature and position of the spots by supposing that the sun revolved on his own axis, or by imagining that other unknown stars, besides Mercury and Venus, revolved about the sun, which were visible only as spots, and invisible at other times on account

[1] "Discourse on Floating Bodies," Florence, 1612.

of their small distance from him. But further observation led him to abandon the latter supposition and to announce positively[1] that the spots were in actual contact with the body of the sun, where they were continually appearing and disappearing, much as clouds about our earth; that their figures were very irregular, some being very dark and others less so; that one would often divide into two or three, and at other times two or three would unite into one; and that they all had a common and regular motion, being carried round with the sun, which turned on its axis in a little less than a lunar month,[2] and in the same direction as the planets.

These observations were, in their consequences to Galileo, particularly unfortunate, as in the course of the controversy in which they entangled him, he first became personally embroiled with the powerful Jesuit party, whose influence was one of the chief causes of his subsequent misfortunes.

A Jesuit father, Christopher Scheiner, Professor of Mathematics at Ingolstadt, claimed priority in the discovery of the Sun-spots, asserting that early in 1611 he first noticed them and showed them to his pupils. Scheiner stated his case in three letters over the signature *Apelles latens post tabulam*, and addressed to Mark Welser, Chief Magistrate of Augsburg. In the first letter dated 12th November 1611, he states that he made his first observations seven months previously; but apparently he then attached no

[1] Letter to Prince Cesi, dated 12th May 1612.

[2] Modern observations make it vary from 25 to 27½ days.

value to them, for, on resuming his work in the following October, he thought the appearances arose from some defect in his glasses—an idea which was only dissipated by these further studies.[1] Clearly then, it was only *after* resuming his observations (October 1611) that he believed in the actual existence of the spots, which he then explained by supposing them to be caused by multitudes of little planets, revolving round the sun in an orbit inside Mercury, and producing the appearance of spots in crossing his disc.

On the publication of Scheiner's letters at Augsburg, Welser, on 6th January 1612, sent a copy to Galileo requesting to be favoured with his opinions of the phenomena therein described. Galileo replied in three letters[2] in which he easily combated Scheiner on the nature of the spots, and stated that his own observations dated back eighteen months.[3]

[1] An amusing incident is related in connection with Scheiner's observations, which shows how the authority of Aristotle held its ascendency over men's minds even when his dogmas were opposed to the testimony of the senses. On communicating his discovery to the Provincial of his Order, the latter replied: "I have read Aristotle's writings from end to end many times, and I can assure you I have nowhere found anything similar to what you describe. Go, my son, and tranquillise yourself; be assured that what you take for spots on the sun are the faults of your glasses, or of your eyes." Scheiner was only permitted to publish his observations anonymously, as mentioned in the text.

[2] The first of which, dated 4th May 1612, is now in the British Museum in autograph; the second is dated 14th August, and the third 1st December. All three were published in 1613 under the title "Istoria e Dimostrazioni delle Macchie Solari."

[3] He says this at the beginning of the first letter, which is dated 4th May 1612. This would fix the date at about beginning of November 1610; yet, from Fra Micanzio's letter to Galileo of 27th September 1631, the first observations would appear to go back

In these letters Galileo further stated that the spots often dispersed like vapours or clouds, which he supposed them to be; that they sometimes lasted only one or two days, and at other times thirty or forty days; that they contracted in breadth as they approached the sun's limb, without diminishing their length; that they described circles parallel to each other; that the rotation of the sun again brought the same spots into view; and that they were never seen to extend to a greater distance than 30° from the sun's equator.[1]

Besides the spots, Galileo's telescope disclosed other interesting appearances on the sun's disc. Some parts are perceived to be brighter than the rest of the surface, and hence are called *faculae.* These phenomena are described in the third letter to Welser, where with great acuteness he adduces them as a proof that the spots *are* attached to the surface of the sun, and are *not* little planets as Scheiner supposed; for the telescope frequently showed spots and *faculae* travelling across the sun's disc together; and, accepting Scheiner's supposition with regard to the former, it would be probable that the latter also should sometimes appear as bright spots *beyond* the sun's limb—a conclusion which was totally at variance with all his observations.

These letters were written from the Villa delle Selve of his friend Filippo Salviati, near Signa

to the time when Galileo was still at Padua, say to August. But writing so long after the event, Micanzio may well be mistaken as to the date.

[1] Appended to the second letter are forty sketches of the spots as observed from day to day during June, July, and August 1612.

(9 miles from Florence), where Galileo spent much of his time at this period, and particularly during his frequent indispositions, as he considered that the air of the city was prejudicial to his complaints.[1]

The letters, with Scheiner's appended, were printed at Rome in March 1613, and were dedicated to Salviati. They were published under the auspices of the Accademia dei Lincei, "In order," as the Academy report sets forth, "to mark its sense of the merit of the work and the claim of its author to be regarded as the first discoverer of Sun-spots."[2]

In order to complete our history of the Sun-spots in so far as Galileo is concerned, we have left unnoticed other important matters on which he was at the same time engaged, and to these we must now return. Soon after his return to Florence in June 1611, he wrote a pamphlet in the usual form of a letter, dated 1st September 1611, and addressed to Father Griemberger, "on

[1] Salviati had ever been one of his warmest friends, and delighted in drawing round him all the great scientists of the time. He was a member of the Accademia dei Lincei, and although not an author of any great work, or of any important discovery, he has yet earned, by his liberality to science, and by his devotion to Galileo, an honoured name that will not die. He died 22nd March 1614, and in after years Galileo raised to his memory a monument more enduring than marble, by assigning to him the place of honour in the immortal Dialogues of 1632, where Salviati is the Copernican interlocutor, and represents, in fact, Galileo himself in the dialogue.

[2] The *first* discovery of Sun-spots has also been claimed for Thomas Hariot in England, for Simon Mayer in Germany, and for Johann Fabricius in Holland. The first two claims rest on very doubtful evidence; the third is better founded. In fact, Fabricius was the first to *publish* the results of his observations in his "De Maculis in Sole Observatis" (Wittenberg, June 1611), and therefore, according to modern notions, he has the best claim to priority. For more, see Grant's "History of Physical Astronomy," pp. 213-15.

the Inequalities of the Moon's surface," or lunar mountains. The moon was with him a stock subject for observation, the results of which he communicated from time to time in letters to (besides Griemberger) Welser, Brengger, Gallanzoni, and others. Indeed, his last astronomical discovery, towards the close of life and just before he became blind, was connected with the moon.

It had been asserted that, as the *full moon* always presented a well-defined outline, whether when viewed with the naked eye, or through a telescope, it was impossible that there could exist any equalities around her circumference. Galileo, however, maintained that the irradiation of the moon's light, by obliterating any asperities around her edge, might effectually conceal the real nature of that part of her surface. With respect to irradiation generally, he remarked that it increases with the brightness of the object. It is from this cause that the planets near the sun have a greater irradiation than those that are more remote. So intense is the irradiation of Mercury, that it is impossible, even with the most powerful telescope, to deprive him of his brilliant corona. The same is true, though in a less degree, with respect to Mars. On the other hand, Jupiter, and especially Saturn, being more feebly illuminated by the solar light, lose their irradiation in the telescope, and disclose their true figures. With respect to Venus, when she is near her inferior conjunction, she resembles the new moon; but such is the intensity of her irradiation, that she appears to the naked eye like any other star. In this position, however,

as the extent of the illuminated surface is small, and the light is at the same time enfeebled by the obliquity of the surface, it is possible by means of a telescope to discern the real appearance of the planet. When, however, she is near her superior conjunction, she presents a complete hemisphere of vivid light towards the earth of such intensity that even the most perfect telescope does not suffice to destroy her irradiation and reveal to us her true figure.

Galileo, therefore, contends that since the effect of irradiation is so great as to conceal from the unaided eye the immense cavity of Venus when she assumes the form of a crescent, it is much more probable that a telescope will fail to efface the irradiation of the moon enough to disclose the small eminences and cavities which may be situated near the edge of her disc.[1]

Like all subsequent observers up to the close of the eighteenth century, Galileo is said to have believed in the existence of lunar seas and of a lunar atmosphere; while on the question of the existence of lunar inhabitants he is supposed to have kept an open mind.[2] His belief in a lunar atmosphere may be conceded, but as regards the

[1] See p. 88 *ante*. Also Grant's "History of Physical Astronomy," pp. 347-52. In one of the frescoes in the Borghese chapel in S. Maria Maggiore, Rome (the Virgin with the moon under foot), by Cigoli, the friend and correspondent of Galileo, the hills and valleys of the moon are painted as the telescopes of the day (1612) revealed them.

[2] As regards the habitation of the planets, however, he was discreetly silent. In a letter to Prince Cesi, 25th January 1613, he says: "If the question be put to me I will answer neither yes nor no." He also refers to the subject in the same indeterminate way in his letters on Sun-spots and in the Dialogues of 1632.

other points the very reverse is the fact, as the following letter shows. Writing to Giacomo Muti from Rome, on 28th February 1616, Galileo says :—

"A few days ago, when paying my respects to the illustrious Cardinal Muti, a discussion arose on the inequalities of the moon's surface. Signor Alessandro Capoano, in order to disprove the fact, argued that if the lunar superfecies be unequal and mountainous, one may say as a consequence that, since Nature has made our earth mountainous for the benefit of plants and animals beneficial to man, so on the moon there must be other plants and other animals beneficial to other intellectual creatures. Such a consequence, he said, being most false, therefore the fact from which it is drawn must also be false, therefore lunar mountains do not exist![1] To this I replied: As to the inequalities of the moon's surface we have only to look through a telescope to be convinced of their existence; as to the 'consequences,' I said, they are not only not necessary, but absolutely false and impossible, for I was in a position to prove that neither men, nor animals, nor plants as on this earth, nor anything at all like them can exist on the moon. I said then, and I say now, that I do not believe that the body of the moon is composed of earth and water, and wanting these two elements we must necessarily conclude that it wants all the other things which without these elements cannot exist or subsist. I added further: even allowing that the matter of the moon may be like that of the earth (a most improbable supposition), still not one of those things which

[1] The work of the peripatetic philosopher Lagalla ("De Phoenomenis in Orbe Lunae," Bologna, 1612), enforcing the same arguments, is reprinted in the later editions of Galileo's works, with his marginal comments.

the earth produces can exist on the moon, since to their production other things besides earth and water are necessary—namely, the sun—the greatest agent in Nature—and the resulting vicissitudes of heat and cold, and of day and night. Now, such vicissitudes are on the moon very different from those on the earth. In the latter case, to produce a diversity of seasons, the sun rises and falls more than 47° (in passing from one tropic to the other); in the former case the variation is only 5° on each side of the ecliptic. While, therefore, on the earth the sun in every 24 hours illuminates all parts of its surface, each half of the moon is alternately in sunshine and darkness for 15 continuous days of 24 hours. Now, if our plants and animals were exposed to ardent sunshine every month for 360 consecutive hours, and then for a similar time were plunged in cold and darkness, they could not possibly preserve themselves, much less produce and multiply. We must, therefore, conclude that what would be impossible on our earth under the circumstances we have *supposed* to exist, must be impossible on the moon where those conditions *do* exist."

No sooner were these questions of sun-spots and lunar mountains out of hand than Galileo became engaged in another protracted discussion, which resulted in another famous treatise, published in Florence in 1612. This is his "Discourse on Floating Bodies," in which he uses the principle of virtual velocities from which modern geometers, and especially Lagrange, have drawn largely, and by the aid of which he demonstrates the more important theorems of hydrostatics.[1]

[1] This important principle was first announced in his treatise on Mechanics, written in 1594. See p. 37 *ante*.

The question of floating bodies had been discussed at one of the scientific parties which the Grand Duke liked to assemble round him, and the general opinion appearing to be that of Aristotle, that the floating or sinking of a body depended principally upon its shape, Galileo undertook to show its untenableness. Some one in the company asserted that condensation is the effect of cold, and ice was mentioned as an instance. Galileo retorted that ice is rather water rarefied than water condensed, the proof of which is that it always floats upon water. His opponents rejoined that this phenomenon was due, not to the lightness of the ice, but to its incapacity, owing to its flat shape, to overcome the resistance which the water opposed to its sinking. Galileo denied this, and asserted that ice of any shape would float upon water, and that if a flat piece of ice were forced to the bottom it would, when left to itself, rise again to the surface.[1]

The general character of this remarkable Discourse will be understood from the following passages:—

"The diversity of figure given to any solid cannot be the cause of its floating or sinking in water; so that if a solid made, for instance, into a sphere sinks or floats, it will likewise sink or float when made into any other form. The breadth of the figure may indeed retard its velocity as well of ascent as of descent, and more and more in proportion to the breadth and thinness of the said

[1] Cardinals Gonzaga and Maffeo Barberini (afterwards Pope Urban VIII.) were among the guests, and the latter took Galileo's side in the discussion against the peripatetics led by Gonzaga.

figure; but that it can be reduced to such a form as to put an end to its motion I hold to be impossible. In this I have met with opponents who, pointing to some experiments, and, in particular, taking a thin board of ebony and a ball of the same wood, and showing that the latter sinks, while the former, if placed lightly on the surface, floats, hold by the opinion of Aristotle that the cause of flotation is the breadth of the figure, which renders it unable to overcome the resistance of the water to penetration; whereas in the case of the ball its form enables it to overcome this resistance, and it readily sinks. I assert, on the contrary, that there is not any solid of such lightness or of such a figure that, being placed on the water, will not divide and penetrate it; and if you examine carefully your thin boards of wood you will see that they have part of their thickness under water; and, moreover, you will see that shavings of ebony, stone, and metal, when they float, have not only broken the continuity of the water, but are *with all their thickness* under the surface, and this more and more according to their specific gravity; so that a thin plate of lead will be lower than the surface of the surrounding water by at least twelve times the thickness of the plate, and a gold plate will dive below the level almost twenty times its thickness."

In order to show more clearly the non-resistance of water to penetration, Galileo then directs a cone to be made of wood or wax, and asserts that when it floats, either with its base or its apex in the water, the solid content of the part immersed will be the same, although the apex is (by reason of its shape) better adapted to overcome the resistance of the water to division. The shape, then,

cannot be the cause of the buoyancy. Or the experiment may be varied by mixing the wax with lead filings till the compound sinks in water, when it will be found that in *any* shape the same weight of cork must be added before it will rise to the surface. He goes on :—

"This silences not my antagonists, who say that my experiments import little to them, and that it is enough for them to have demonstrated in one instance, and in such manner as pleases them best, that an ebony ball when put into water sinks to the bottom, while an ebony board stays to swim at the top, and the matter being the same, and the two bodies differing in nothing but in figure, they affirm that with all perspicuity they have demonstrated and sensibly manifested what they undertook. Nevertheless, I believe and think I can prove that this very experiment proves nothing against my theory. And first, it is false that the ball sinks and that the board does not; for the board will sink too, if you do to both as the words of our question require ; that is, if you put them both *in* the water; for to be in the water implies to be placed in the water; and, by Aristotle's own definition of place, to be placed imports to be environed by the surface of the ambient body. But when my antagonists show the floating board of ebony they put it not into the water, but upon the water, where, being detained by a certain impediment (of which more anon), it is surrounded partly by water, partly by air, which is contrary to our agreement, for that was that the bodies should be in the water, and not part in the water, part in the air. I will not omit another reason, founded upon experience, and, if I deceive not myself, conclusive against the notion that figure and the resistance of the water to penetration have

anything to do with the buoyancy of bodies. Choose a piece of wood or other matter, as for instance walnut-wood, a ball of which rises from the bottom of the water to the surface more slowly than a ball of ebony of the same size sinks, so that clearly the ball of ebony divides the water more readily in sinking than does the walnut in rising. Then, take a board of walnut-wood equal to and like the floating ebony of one of my antagonists, and if it be true that this latter floats by reason of the figure being unable to penetrate the water, the other of walnut-wood, without all question, if thrust to the bottom ought to stay there, as having the same impeding figure, and in consequence unable to overcome the said resistance of the water. But if we find by experience that not only the thin board, but every other figure of the same walnut-wood, will return to float, as unquestionably we shall, then I must desire my opponents to forbear to attribute the floating of the ebony to the figure of the board, since the resistance of the water is the same in rising as in sinking, and the force of ascension of the walnut-wood is less than the ebony's force for going to the bottom.

"Now, let us return to the thin plate of gold or silver, or the thin board of ebony, and let us lay it lightly upon the water, so that it may stay there without sinking, and carefully observe the effect. It will appear clearly that the board or plate is lower than the surface of the water, which rises up and makes a kind of rampart round it on every side. But if it have already penetrated and overcome the continuity of the water, and is of its own nature heavier than the water, why does it not continue to sink, but stop and suspend itself in that little dimple that its weight has made in the water? My answer is, because in sinking till its surface is below

the water, which rises up in a bank round it, it draws after and carries along with it the air above it, so that that which descends is not only the board of ebony (or metal plate), but a compound of ebony and air, from which composition results a body no longer specifically heavier than the water, as was the ebony or metal alone. But, gentlemen, we want the same matter; you are to alter nothing but the shape, and therefore have the goodness to remove this air. This may be done simply by washing the upper surface of the board, for the water having once got between the board and the air will run together, and the ebony will sink to the bottom; and if it does not, you have won the day. But methinks I hear some of my antagonists cunningly opposing this, and telling me that they will not on any account allow their board to be wetted, because the weight of the water so added, by making it heavier than it was before, forces it to the bottom, and that the addition of new weight is contrary to our agreement.

"To this I answer first, that nobody can suppose bodies to be put into water without wetting them, nor do I wish to do more to the board than you do to the ball. Moreover, it is not true that the board sinks on account of the weight of the water added in the washing; for I will put ten or twenty drops on the floating board, and so long as they stand separate it shall not sink; but if the board be taken out, and all that water wiped off, and the whole surface be bathed with a single drop, and be again put upon the water, there is no question but it will sink, water running to cover it, being no longer hindered by the air. In the next place, it is altogether false that water can in any way increase the weight of bodies immersed in it, for water has no weight in water, since it does not sink. Now, just as he who should say that brass by its

own nature sinks, but that when formed into a kettle it acquires from that figure a virtue of lying in the water without sinking, would say what is false, because that is not purely brass which then is put into the water, but a compound of brass and air; so is it neither more nor less false that a thin plate of brass or ebony swims by virtue of its dilated and broad figure.

"Some may wonder that I affirm this power to be in the air of keeping a board or metal plate from sinking, as if in a certain sense I would attribute to the air a kind of magnetic virtue for sustaining heavy bodies with which it is in contact. To satisfy all these doubts, I have contrived the following experiment to demonstrate how truly the air does support these solids; for I have found, when one of these bodies (which floats when placed lightly on the water) is thoroughly bathed and sunk to the bottom, that, by carrying down to it a little air, without otherwise touching it in the least, I am able to raise and carry it back to the top, where it floats as before. To this effect I take a ball of wax, and with a little lead make it just heavy enough to sink very slowly to the bottom, taking care that its surface be quite smooth and even. This, if put gently into the water, submerges almost entirely, there remaining outside only a very little of the top, and, so long as it is thus joined to the air, the ball floats; but if we take away the air, by wetting this top, the ball sinks to the bottom, and remains there. Now to make it return to the surface by virtue of the air which before sustained it, thrust into the water a glass, with the mouth downwards, which will carry with it the air it contains; move this downwards towards the ball, until you see that the air has reached the top of it; then gently draw the glass upwards and you will see the ball rise, and afterwards stay on the top of the water, if you

carefully withdraw the glass without too much disturbing the water. There is therefore a certain affinity between the air and other bodies, which holds them united, so that they separate not without a kind of violence, just as between water and other bodies; for in drawing such bodies wholly out of the water, we see it follow them, and rise sensibly above the level before it quits them."

His opponents were in hopeless confusion between the phenomena of hydrostatic pressure, which they professed to be discussing, and those of capillary action which they quoted against Galileo. With his careful observations to support him, Galileo would have carried conviction more readily had he emphasised the distinction between the two questions, and realised himself that the floating plate of metal indicated a natural property of liquids which deserved special investigation.

Having established his theory of buoyancy by these ingenious experiments, Galileo proceeds to show what must be the dimensions of a plate of any substance which will float as the wax does, assuming in each case that we know the greatest height at which the rampart of water will stand round it. In like manner he shows that a pyramidal or conical figure may be made of any substance in such a way that, by the help of the air, it shall rest upon the water without wetting more than its base; and, furthermore, that we may form a cone of any substance so that it shall float (partially submerged) if placed gently on the surface with its point downwards, whereas no care or pains will enable it to do so with its base down-

wards, owing to the different proportions of air which in the two positions are in contact with the water.[1]

As may be gathered from the foregoing excerpts, the book contains many ingenious experiments and much acute reasoning in support of the true principles of hydrostatics. Like all his other works it encountered violent opposition, and Galileo had, more than once, to enter the field to repel the counter "arguments" of his opponents. The first published attack was by Giorgio Coresio, a professor in Pisa, under the form of a letter to the Archbishop of Florence. The reply to this was entrusted to Galileo's valiant disciple and champion, Benedetto Castelli. The manuscript was submitted to the Master and revised by him, and was about to be published when Coresio was dismissed (on its leaking out that though professedly a Catholic he really belonged to the Greek Church), and died soon after. Thereupon, the work was laid aside, on the principle *de mortuis nil nisi bonum.* A second attack was published anonymously, but was well known to be the work of Arturo d'Elci, head of the University of Pisa, the same who, as we shall presently see, forbade any allusions in lectures to the astronomical discoveries of Galileo. To this Galileo replied in a long letter, dated 4th January 1613, and addressed to Tolomeo Nozzolini.[2] More elaborate attacks were next published by Lodovico delle Colombe

[1] Galileo took advantage of a second edition of this publication to record briefly his latest observations on Venus, on Jupiter's moons, and on the Sun-spots, all of which were, until then, only known to his friends and correspondents. This edition appeared in August, two months after the first.

[2] Nozzolini had previously defended Galileo's views against the attacks of d'Elci and Coresio in a letter (22nd September) to Mgr. Marzimedici, Archbishop of Florence.

and Vincenzio di Grazia. To these a detailed and overwhelming answer was printed in the name of Benedetto Castelli. After pulverising all the "arguments" of his opponents, the writer tauntingly bids them remember that he was merely Galileo's pupil, and thence to conclude how much more effectually Galileo himself would have confuted them had he thought it worth his while.[1]

It was in reference to this controversy that Galileo declared that ignorance had been the best master he ever had, since, in order to be able to demonstrate to his adversaries the truth of his conclusions, he had been forced to prove them by such a variety of experiments as made himself doubly confident; though to satisfy his own mind alone he had never felt it necessary to make many.

[1] It was not generally known till several years after Galileo's death, that Castelli's essay was in fact written by the Master himself. It is entitled "Risposta alle Opposizioni del Colombe e del Grazia," Florence, 1615.

# CHAPTER VIII

## GATHERING STORMS—FIRST APPEARANCE BEFORE THE INQUISITION AT ROME—RETURN TO FLORENCE

## 1612-1617

THE uncompromising boldness with which Galileo published and supported his opinions had, as we have seen so often, raised against him a host of enemies, who each had objections peculiar to himself, but who now began to perceive the policy of uniting their strength in the common cause to crush, if possible, so strange an innovator. The Aristotelian professors, the Jesuits, the political churchmen, and those timid but respectable persons who at all times dread innovation, whether it be in religion or in science, all were drawn together against the philosophical tyrant who threatened them with the penalties of too much knowledge.

The party of Galileo though weak in numbers was not without power and influence. He had trained around him a devoted band who idolised his genius, and disseminated his views, for many of his favourite pupils were now professors in the leading schools of Italy.

No longer able to combat Galileo's hard facts and powerful arguments by asserting that the facts were faults in his glasses and instruments

devilishly designed, and that his arguments were vain-glorious and "scientifically" absurd, his opponents now took their stand on theology, and raised the cry of the Church in danger. On the simple ground that his astronomical doctrines were incompatible with Scripture, a great din was raised and began to make itself heard, especially in Florence, early in the year 1612.

With the first mutterings of the storm in his ears, Galileo wrote thus to Prince Cesi on 12th May in that year:—

"I suspect that this new discovery [the Sun-Spots] will be the signal for the funeral, or rather for the last judgment of the pseudo-philosophy—the funereal signals having already been shown in the moon, the Medicean stars, Saturn, and Venus. And I expect now to see the peripatetics put forth some grand effort to maintain the immutability of the heavens!"

True to her original attitude of hostility, Galileo's *Alma Mater*, Pisa, was consistent and persistent in her opposition to his teachings. Thus, Father Castelli, who in October 1613, was called to the Mathematical Chair in that University, told Galileo (6th November 1613) that he was forbidden to treat in his lectures of the double motion of the earth, or even to hint at its probability! "Of our controversies," he goes on to say, "not a word whatever, a thing which astonishes me. Your marvellous discoveries are scarcely known here even by name!"

Notwithstanding all this commotion in the schools and amongst the minor churchmen, the

authorities at Rome had not yet taken the alarm. On the contrary, we find the Cardinals Maffeo Barberini (afterwards Pope Urban VIII.) and Federigo Borromeo thanking Galileo for sending them his book on the Sun-Spots, and expressing their admiration for his researches as described therein. Similarly, Battista Agucchia, one of the principal officials of the Papal Court, writing 8th June 1613, expressed his belief that Galileo's teachings would in time be universally acknowledged.

"Although now they had many opponents, partly from their novelty and extraordinary character, and partly from the envy and obstinacy of those who had from the first maintained the contrary opinion."

But amongst his other friends (not in Rome) there was at least one more discriminating, one who knew better the men and their spirit—Fra Paolo Sarpi of Venice. This old and faithful friend did not share this confidence in the triumph of truth—"I foresee," said he, "that the ecclesiastical authorities will change a question of physics and astronomy into one of theology, and that to my great grief Galileo, if he wants to live in peace and escape the charge of heresy, will have to recant." "The day will come," he continues, "when men of science will have to deplore the disgrace of Galileo." Prophetic words, as the sequel will show.[1]

An accidental circumstance was the spark which fired the train. One day in December 1613,

[1] Griselini, "Del Genio di Paolo Sarpi," Venice, 1785, vol. ii. p. 70. Professor Favaro, however, doubts their authenticity, and questions Griselini's authority.

Castelli and other learned men were guests at the Grand Duke's table at Pisa, where, as usual, the Tuscan Court was wintering. The conversation turning on the "satellites of Jupiter," Castelli took the opportunity of extolling and expatiating on his master's discoveries. One of the guests, Boscaglia, Professor of Physics at the University, and a peripatetic of the purest water, managed to excite the religious scruples of Cristina, Dowager Grand Duchess, by telling her that all Galileo's telescopic discoveries were true, only the deduction from them of the double motion of the earth must be wrong, as the Holy Scriptures were clearly opposed to such a doctrine. Castelli, who had left the apartment, was recalled to answer this objection. At first he deprecated bringing the Bible into the controversy, but as this was unavailing, he resolutely took the theological standpoint, and defended the new views of the universe so well, that many of those present took his side—the Dowager Duchess standing alone, and Boscaglia taking no part. Castelli hastened to apprise Galileo of this incident, and added that it appeared to him that the Grand Duchess had merely persisted in opposition, in order to draw him out. —(Letter of 14th December 1613.)

This, then, was the provocation to Galileo's famous letter of 21st December 1613 to Castelli, in which for the first time he engages in theological discussions, and which, although not intended for publication, was to be turned to account by his enemies, and to form the groundwork of his subsequent trial. The letter is too long to quote

in full, but the following passages will show the line of argument pursued.[1] He begins by showing that there is as much difficulty in reconciling the Ptolemaic as the Copernican system of the world with the astronomical expressions contained in the Scriptures, and asserts that (the object of Scripture not being to teach astronomy) such expressions are there used as would be intelligible to the vulgar, and without regard to the true structure of the universe.[2] He then goes on:—

"As the Bible, although dictated by the Holy Spirit, admits (for the reasons given above) in many passages of an interpretation other than the literal one, and as, moreover, we cannot maintain with certainty that *all* interpreters are inspired by God, I think it would be the part of wisdom not to allow any one to apply passages of Scripture in such a way as to force them to support as true any conclusions concerning nature, the contrary of which may afterwards be revealed by the evidence of our senses, or by actual demonstration. Who will set bounds to man's understanding? Who can assure us that every thing that can be known in the world is known already? . . . I am inclined to think that Holy Scripture is intended to convince

[1] This letter, with the one from Castelli which called it forth, is given in full in "Private Life of Galileo," London, 1870, pp. 73-7.

[2] When the intrigues against Galileo began in Florence 1611-12, he consulted Cardinal Conti as to how far the Scriptures were favourable to the Aristotelian constitution of the world. Conti replied, 7th July 1612, that the Scriptures were rather contrary than favourable to the peripatetic doctrine of the incorruptibility of the heavens; but he was not so sure on the question of the motion of the earth. He thought that this opinion could not be reconciled with passages in Scripture which attributed motion to the sun and stars only, except on the assumption that the Scriptures employed a popular form of expression—a form understandable by the vulgar, but which was not necessarily and rigorously true to the facts.

men of those truths which are necessary for their salvation, and which being far above man's understanding cannot be made credible by any learning, or by any other means than revelation. But that the same God who has endowed us with senses, reason, and understanding, does not permit us to use them, and desires to acquaint us in another way with such knowledge as we are in a position to acquire for ourselves by means of those faculties—*that*, it seems to me I am not bound to believe, especially concerning those sciences about which the Holy Scriptures contain only small fragments and varying explanations; and this is precisely the case with astronomy, of which there is so little that the planets are not all enumerated, only the sun and moon, and once or twice Venus under the name of Lucifer. This, therefore, being granted, I think that in discussing natural phenomena we ought not to begin with texts from Scripture, but with experiment and demonstration, for from the Divine Word Scripture and Nature do alike proceed. And I can see that that which experience sets before our eyes concerning natural effects, or which demonstration proves unto us, ought not upon any account to be called in question, much less condemned, upon the testimony of Scriptural texts, which may (under their mere words) have meanings of a contrary nature. . . ."

The letter concludes with a long discussion of Joshua's miracle, ending in a *reductio ad absurdum.*

Castelli, seeing nothing objectionable in this letter, gave it a wide circulation in written copies. But not so the enemies of Galileo, who eagerly seized it as a weapon to be used against him. They turned his emphatic opinion that the Scrip-

tures had no business in scientific controversy into the reproach that he assailed the universal authority of the Bible, and, referring to his explanation of Joshua's miracle, they loudly demanded that the Scriptures must be protected from the arbitrary interpretations of profane laymen.

After some months of underhand agitation, Father Caccini of the Dominican convent of San Marco was the first to declare war openly, in a sermon from the pulpit of Santa Maria Novella in Florence. Preaching on the fourth Sunday in Advent (December) 1614, and selecting as his texts chap. x. vers. 12, 13, of Joshua, and chap. i. ver. 11, of Acts, he began with the words: "Ye men of Galilee! why stand ye gazing up into heaven?" He asserted that Galileo's doctrine of the earth's revolution round the sun was irreconcilable with the holy Catholic faith, since it contradicted several passages in Scripture. He reminded his hearers that no one was permitted to interpret the Bible in any other sense than that adopted by the Fathers; he as good as denounced Galileo's teachings as heretical; and wound up with a coarse attack on mathematicians in general, whose science he called an invention of the devil, and who should be banished from all Christian states, since all heresies proceeded from them. A preacher at the Duomo (cathedral), a Jesuit strange to say, replied, and undertook to show that Copernicus was right; that Galileo and his followers were good Catholics; and that Caccini and the Dominicans generally were

ignorant fools! As may be imagined, this line of argument added fuel to the fire, and the result was a great commotion in Florence. This fierce attack made Galileo lose patience; he wished to publicly resent the insults, but on the advice of friends he kept quiet, and the storm subsided for a while.

The man who first brought Galileo's affairs before the Inquisition (or the Holy Office) was one Father Lorini, a friend of Caccini and a member of the same convent. This man was Professor of Ecclesiastical History in Florence, and was from the beginning of 1612 a ringleader of all the local intrigues against Galileo. A copy of the letter to Castelli had come into his hands, and this, after Caccini's fierce sermon, he sent to the Holy Office in Rome with an unsigned denunciation, dated 5th February 1615, and addressed to Cardinal Mellini, President of the Congregation of the Index. This document was most artfully drawn up; too cowardly to mention Galileo by name, as he knew him to have friends at the Vatican, he denounces the Galileists in general, "who maintain agreeably to the doctrine of this man Ipernic, or whatever they call him, that the earth moves and the heavens stand still." "All the fathers," he goes on, "of this devout convent of San Marco find many passages in this letter which are suspicious and presumptuous, as when it says (1) that many expressions of Holy Scripture are indefinite; (2) that in discussions about natural phenomena the lowest place must be assigned to them; (3) that the commentators have often been mis-

taken in their interpretations; (4) that the Scriptures should not be mixed with anything but matters of religion; (5) that in nature philosophical and astronomical evidence is of more value than Holy writ; and finally (6) that when Joshua commanded the sun to stand still we must only understand that the command was addressed to the *primum mobile*, and not to the sun"; and so on, and so on.

In consequence of this denunciation the Holy Office instituted a secret enquiry. As Lorini had only sent a copy of the letter to Castelli, the Inquisition took steps to gain possession of the original, written and signed by Galileo, and wrote (26th February 1615) to the Archbishop of Pisa to procure the document "in a skilful manner." But in this they were foiled; Castelli no longer possessed the letter, having returned it to Galileo, and the latter, on being asked for it again, supplied only a copy, unsigned and undated, and which, moreover, he strictly enjoined Castelli not to let out of his hands. Castelli accordingly read the letter to Archbishop Bonciani (in presence of several canons of his cathedral), who concealed as well as he could his annoyance at the failure of his scheme. So, Cardinal Mellini had to be content with Lorini's copy of the incriminated letter, which was submitted to the Councillor of the Holy Office for his opinion. His report was a colourless one: some passages were objectionable, but, although at first sight they looked ill, they were capable of being taken in a good sense, and on the whole the document was not of that

nature that it could be said to deviate from Catholic doctrine.

Meanwhile, Caccini, who had been transferred to Rome, was summoned as one specially well-informed about Galileo's teachings! His evidence was a repetition of his sermon, mixed up with all the tittle-tattle of Florence. After denouncing Galileo and his works as Godless, he concluded, "at any rate he is suspicious in religious matters, *because* he belongs to a certain Accademia dei Lincei, and corresponds with the Godless Fra Paolo Sarpi at Venice, and with many Germans."

Galileo appears to have known nothing accurately of these proceedings. He could only learn that some Dominican monks were making use of his letter to Castelli in order to effect the condemnation of the Copernican doctrines. Fearing that the copy on which they relied at Rome might have been tampered with, he sent a correct copy, on 16th February 1615, to his friend and old pupil, Mgr. Piero Dini, with a request that he would forward it to Father Griemberger, and perhaps also to Cardinal Bellarmine. He added that he had written to Castelli *currente calamo*, and that he had since made many researches into the matters therein discussed, which he was embodying in a larger treatise—a copy of which when finished he would send.[1] Mgr. Dini in reply, and apparently as the result of a conference with Cardinals del Monte and Bellarmine, urged Galileo to hurry on his writing, but at the

[1] This was his celebrated letter or Apology addressed to the Grand Duchess Cristina.

same time advised caution, to avoid theology, and to confine himself to mathematics and physics. "Write freely," he said, "but be careful to keep outside the sacristy." Mgr. Ciampoli, another (Florentine) disciple then residing in Rome, writing 28th February, conveyed the assurance of Cardinal Maffeo Barberini that he had Galileo's interests at heart, and that it would be more prudent not to go beyond his *rôle* of Professor of Mathematics, as the theologians claimed to have the sole right of explaining the Scriptures. Prince Cesi gave him much the same advice, and added his belief that any deliberate formulation of the Copernican doctrine would only end in its prohibition, and the suppression of his book. This excellent advice unfortunately came too late, for, as we see, the Inquisition was already moving; and even if Galileo had never written his letter to the Grand Duchess, or had written it in the way suggested, his enemies already had grounds enough to go upon.

Although down to the end of June 1615, Galileo received reassuring letters from Rome, that there was nothing in progress at which he need be at all disconcerted, yet, so well did the Inquisition keep its secret, it was all the time laying its plans to entrap him.[1]

Meanwhile, about the middle of 1615, Galileo

[1] From 20th June 1615, to Galileo's visit to Rome in the following December, but two letters from his Roman friends are extant, which, considering the anxious period covered, is remarkable. Von Gebler thinks it probable that Galileo destroyed the correspondence out of regard for his friends. "Galileo and the Roman Curia," London, 1879, p. 64.

completed his great apologetic treatise in the form of a letter to the Dowager Grand Duchess Cristina, in which he defines at great length his position as a natural philosopher, and as a sincere member of the Church of Rome. It is, naturally, an amplification of his letter to Castelli already quoted, and need not, therefore, be more fully noticed.[1] The pith of it is contained in the saying of Cardinal Baronius, which the author quotes :—

"The Holy Spirit intended to teach us in the Bible how to go to heaven, not how the heavens go."

The concluding passages may be quoted as follows :—

"Again, to command professors of astronomy that they must themselves see to confuting their own observations and demonstrations is to ask the impossible, for it is not only to command them not to see what they do see, and not to understand what they do understand, but to seek for and to find the contrary. I would entreat these wise and prudent Fathers to consider diligently the difference between opinionative and demonstrative doctrines, to the end that they may assure themselves that it is not in the power of professors of demonstrative sciences to change their opinions at pleasure, and adopt first one side and then the other; that there is a great difference between ordering a mathematician, or a philosopher, as to what opinion to hold, and doing the same with a merchant, or a lawyer, since

[1] Von Gebler gives an excellent *résumé*, at pp. 64-70 of "Galileo and the Roman Curia." The Apology and the letter to Castelli were not published until after the trial of 1633, and then apparently with the object of showing the learned world how unjust his condemnation was.

demonstrated conclusions touching things of nature and of the heavens cannot be changed with the same facility as opinions touching what is lawful, or not, in a contract, bargain, or bill of exchange.

"Therefore, let such people apply themselves to the study of the arguments of Copernicus and others, and leave the condemning of them as erroneous and heretical to whom it belongeth. Yet, as to this latter, they must not hope to find such rash and precipitate determinations in the wary Holy Fathers, or in the absolute wisdom of him who cannot err (the Pope), as those into which they suffer themselves to be hurried by some particular affection or interest of their own. In these, and such like opinions which are not directly articles of faith, certainly no man doubts that his Holiness hath always an absolute power of admitting or condemning them; but it is not in the power of any creature to make them to be true or false, otherwise than as, in fact, they are."

This letter, notwithstanding its moderate and even deprecating tone, was, of course, a fresh weapon against him, and his enemies denounced him more noisily than ever. Ominous reports began to circulate, but still Galileo could not learn any thing more definite than that something was brewing against him, and that the Copernican theory would probably be interdicted. Thinking that he could best combat these intrigues by going to Rome, he set out early in December 1615, provided with cordial letters from the Grand Duke to his Ambassador Guicciardini, to Cardinals del Monte and Orsini, and others. His enemies spread about that this step did not originate with

himself, but was the result of a direct citation. This, however, is abundantly disproved by the Grand Duke's letters in which he distinctly says that Galileo goes to Rome of his own accord (*spontaneamente*).

His reception by the authorities seemed to be cordial, but he quickly discovered that a zealous agitation was going on, not only against his teachings but against himself. However, he was confident that he should very soon destroy the traps of his enemies, and justify himself in a way that would bring discredit upon themselves. Judging from a letter of some days later, 23rd January 1616, to Secretary Picchena, he had not found his defence so easy as he anticipated. He says :—

"My business is far more difficult and takes much longer, owing to untoward circumstances, than the nature of it would require. I cannot communicate directly with those persons with whom I have to negotiate—partly to avoid doing injury to any of my friends, and partly because they cannot communicate anything to me without running the risk of grave censure. So I am compelled with much pains and caution to seek out third persons who, without even knowing my object, may serve as mediators with the principals. . . . I have also to set down some points in writing, and to cause that they shall come privately into the hands of those whom I wish to see them."

At length Galileo succeeded, as he thought, in freeing himself personally from all accusations and in refuting the slanders of Caccini and his confederates. The monk paid him a long visit, humbly begged pardon for his previous conduct,

and offered any satisfaction in his power. But Galileo rightly gauged his sincerity, in a letter to Picchena of 20th February, in which he says:—

"I perceived not only his great ignorance, but that he has a mind void of charity and full of venom."

Lorini excused himself in a still more contemptible manner. He coolly admitted that he knew nothing and wanted to know nothing of the merits of the controversy. He only acted "for the sake of saying something, lest men should think that the Dominican Fathers were asleep or dead."

But by adjusting his own difficulties Galileo had performed only half the task he set himself. The grander part of it, viz. the preservation of the Copernican doctrines from the interdict of the Church, had yet to be accomplished.

"My business, so far as it concerns myself, is completed. All the exalted personages who have been conducting it have told me so plainly and in a most obliging manner, and have assured me that people are fully convinced of my uprightness and honour, and of the devilish malice and injustice of my persecutors. As far, therefore, as this matter is concerned I might return home without delay; but there is a question connected with my case, which does not concern myself alone, but all those who during the last eighty years have advocated, in printed works and private letters, in public lectures and private conversations, a certain theory not unknown to your Excellency, on which they are now proposing to pronounce judgment. In the hope that my assistance may be of use in this matter, so far as a knowledge of those truths is

concerned which are proved by the science to which I have devoted myself, I as a zealous and Catholic Christian neither can nor ought to withhold that assistance which my knowledge affords; and this part of the business keeps me fully employed."—(Letter to Picchena, 6th February 1616).

As illustrating his manner of assisting the Copernican cause, the following letter from Antonio Querengo to Cardinal d'Este, 20th January 1616, is interesting.

"Your Reverence[1] would be delighted with Galileo if you heard him holding forth, as he often does, in the midst of fifteen or twenty, all violently attacking him, sometimes in one house, sometimes in another. But he is armed after such fashion that he laughs all of them to scorn; and even if the novelty of his opinions prevents entire persuasion, at least it convicts of emptiness most of the arguments with which his adversaries endeavour to overwhelm him. He was particularly admirable on Monday last, in the house of Signor Federigo Ghisilieri; and what especially pleased me was that, before replying to the contrary arguments, he amplified and enforced them with new grounds of great plausibility, so as to leave his adversaries in a more ridiculous plight when he afterwards overturned them all."

This entering the lists in the cause of Copernicanism was, to say the least, magnanimous, and Galileo was entitled as no other was to appear as an advocate; but unfortunately his warm and, perhaps, too solicitous efforts in the cause had a

[1] The title Eminence was not conferred on Cardinals until twelve years later.

result precisely opposite to the one he intended. The fact is, Galileo's too sanguine temperament deceived him woefully as to the true course of these transactions, as we shall also find to be the case in his second and more terrible encounter with the Holy Office; for, a few days after he thought his own affairs so satisfactorily settled that he could if he chose return to Florence in triumph, a bolt shot out of the blue which paralysed him, and spread consternation among his friends. Without any warning (for such was the manner of the Inquisition), on 19th February, the Qualifiers, or official experts, of the Holy Office were called on for an opinion on the following propositions extracted from Galileo's work on the Sun-spots:—

(1) The sun is the centre of the world, and, therefore, immovable from its place.

(2) The earth is not the centre of the world, and is not immovable, but moves, and also with a diurnal motion.

On the 24th February the Qualifiers reported:—

(1) The first proposition is unanimously declared to be false and absurd philosophically, and formally heretical, inasmuch as it expressly contradicts the doctrines of Holy Scripture in many passages, both if taken in their literal meaning and according to the interpretation of the Holy Fathers and learned theologians.

(2) The second proposition is declared unanimously to deserve the like censure (as the first) in philosophy, and, as regards its theological aspect, to be at least erroneous in faith.

On 25th February, Cardinal Mellini reported this opinion to the Holy Office, and, as the result, Cardinal Bellarmine was directed "to summon before him the said Galileo, and admonish him to abandon the said opinion; and in case of refusal the Commissary is to intimate to him, before a notary and witnesses, a command to abstain altogether from teaching or defending the said opinion, and even from discussing it; and if he do not acquiesce therein he is to be imprisoned."

This admonition was administered on the next day, as appears from the following minute:—

"Friday, the 26th. At the palace, the usual residence of the Lord Cardinal Bellarmine, the said Galileo, having been summoned and brought before the said Lord Cardinal, was, in presence of the Most Revd. Michelangelo Seghizzi, of the order of preachers, Commissary-General of the Holy Office, warned by the said Lord Cardinal of the error of the aforesaid opinion and admonished to abandon it. And immediately thereafter before me and before witnesses, the Lord Cardinal Bellarmine being still present, the said Galileo was by the said Commissary commanded and enjoined, in the name of his Holiness the Pope, and the whole Congregation of the Holy Office, to relinquish altogether the said opinion, that the sun is the centre of the world, and immovable, and that the earth moves; nor henceforth to hold, teach, or defend it in any way whatsoever, verbally or in writing; otherwise proceedings would be taken against him in the Holy Office; which injunction the said Galileo acquiesced in and promised to obey.

"Done at Rome, in the palace aforesaid, in the presence of Badino Nores, of Nicosia, in the Kingdom of Cyprus, and Augustino Mongardo,

from a place in the abbacy of Rose, in the diocese of Politianeti, inmates of the said Cardinal's house, witnesses."[1]

Here the process ended so far as Galileo was concerned, but it was followed up a few days later by an edict prohibiting and suspending certain writings, amongst them the book of Copernicus. This decree runs as follows:—

"March 3, 1616. The Lord Cardinal Bellarmine having reported that Galileo Galilei, mathematician, had, in terms of the order of the Holy Congregation, been admonished to abandon the opinion he has hitherto held, and had acquiesced therein; and the decree of the Congregation of the Index having been presented, prohibiting and suspending respectively the writings of Nicolas Copernicus on 'The Revolutions of the Celestial Orbs'; of Diego di Zuniga 'On Job'; and of Paolo Antonio Foscarini, Carmelite friar; his Holiness has ordered this edict of prohibition and suspension respectively to be published as follows:—

"March 5, 1616 [after preamble]. And whereas it has also come to the knowledge of the said Congregation that the Pythagorean doctrine (which is false and altogether opposed to Holy Scripture) of the motion of the earth and the quiescence of the sun, which is also taught by Nicolas Copernicus in his 'Revolutions of the Celestial Orbs,' and by Diego di Zuniga in his book 'On Job,' is now being spread abroad and accepted by many—as may be seen from a certain letter of a Carmelite father, wherein he attempts to show that the aforesaid doctrine is consonant with

[1] It should be noted that this minute bears no signature, neither of Cardinal, Commissary, and witnesses, nor of Galileo.

truth and is not opposed to Holy Scripture. Therefore, in order that this opinion may not insinuate itself any further to the prejudice of Catholic truth, the Holy Congregation has decreed that the said works of Nicolas Copernicus and Diego di Zuniga be suspended until they be corrected; that the book of the Carmelite, Foscarini, be altogether prohibited and condemned; and that all other books in which the same doctrine is taught be likewise prohibited."[1]

It should be noted that the book of Copernicus was only suspended until corrected. These "corrections," which were of the most trivial character, were carried out under the supervision of Cardinal Gaetani in 1620, after which it would be allowable to read the book, and its doctrines could be held by the faithful, "*ex hypothesi*, and without affirming anything."[2]

[1] The Diego di Zuniga mentioned in this decree was a professor in Salamanca, who in 1584 adopted the Copernican theory as not opposed to Scripture. Foscarini's letter of 6th January 1615 was addressed to the General of his Order, and in it he accepts Galileo's discoveries as proof of the truth of the Copernican theory. One passage is worth quoting:—

"Holy Church with its visible head, the Pope, assisted by the Holy Spirit, cannot err in questions of faith, but it can err in its judgments of practical questions, in philosophic speculations, and other matters which are not concerned with our salvation."

This was precisely Galileo's contention throughout all these polemics.

[2] They consisted in the omission of a few passages in the preface, and in the alteration of certain words in the text, as, notably, the word "star" when applied to the earth. Also such words as stated or implied that the hypothesis was true were altered so as to make it one of mathematics pure and simple, and without any pretension to reality. As no one cared to bring out an edition of Copernicus in this bowdlerised state, his book remained prohibited in Italy for over two hundred years.

Galileo remained in Rome for nearly three months after the promulgation of the decree of 5th March. His enemies spread the report that he had been obliged to recant formally and to abjure his opinions. It would be easy to show his friends how grossly exaggerated was this report; but in order the better to confute these calumnies, and to guard against them in the future, he obtained a paper from Cardinal Bellarmine, stating the facts as follows:—

"We, Robert Cardinal Bellarmine, having heard that it is calumniously reported that Signor Galileo Galilei has in our hand abjured, and has also been punished with salutary penance, and being requested to state the truth as to this, declare that the said Signor Galileo Galilei has not abjured, either in our hand or the hand of any other person here in Rome, or anywhere else, so far as we know, any opinion or doctrine held by him; neither has any salutary penance been imposed upon him, but only the declaration made by the Holy Father, and published by the sacred Congregation of the Index, has been intimated to him, wherein it is set forth that the doctrine attributed to Copernicus—that the earth moves round the sun, and that the sun is stationary in the centre of the world, and does not move from east to west—is contrary to the Holy Scriptures, and therefore cannot be defended or held.

"In witness whereof we have written and subscribed these presents with our hand this 26th day of May 1616."

We have been careful to give the principal documents connected with this momentous process, for upon them, and especially upon the unsigned

minute of 26th February, hinge the charges on which Galileo was brought before the Inquisition in 1633, and his defence. Von Gebler and other critical historians in recent times conclude that the minute of 26th February is spurious—concocted by enemies, and placed among the acts of the case with the hope of being useful at some future time. Von Gebler says:—

"In common with other critics, we ourselves had long been of opinion that this note originated not in 1616 but in 1632, in order to legalise the trial of Galileo begun in the latter year. But after repeatedly and very carefully examining the original papers, preserved among the Papal archives, we were compelled to acknowledge that the material nature of the document entirely excludes the suspicion of a subsequent fabrication. The note was not fabricated in 1632, but, probably, in 1616. With subtle and perfidious calculation a lie was then entered, which was to have the most momentous consequences for the great astronomer."[1]

Von Gebler discusses this question at great length, but he does not convince us that his view is the right one. That the document is *not* a forgery of the year 1616 seems to us sufficiently proved by the facts that it lay buried for sixteen years, its existence not even hinted at, and that it was only accidentally discovered late in 1632, to the surprise of every one. Were it a forgery with a purpose, its authors would be sure to bring it up in the fierce discussions over the comets of 1618-19, or over Galileo's "Il Saggiatore" of 1623,

[1] "Galileo and the Roman Curia," p. 90.

which contained "heretical" teaching, and which, as we shall see, was a *bête noire* of the Jesuits, or, finally, immediately after the publication of his Dialogues early in 1632. That Galileo himself in after years said it was a forgery—part of a deep-laid plan to crush him—we can excuse as the hasty expression of an outraged man writhing under persecution.

The learned Professor Favaro, who has for the last twenty-five years made a study of Galileo's life and works, takes the opposite view to Von Gebler. He also has very carefully examined the Vatican MSS., and can come to no other conclusion than that the document in question is genuine and *bonâ fide;* that it was drawn up at the time, and put in its place, as a record of what actually happened, and with no sort of *arrière pensée.*

Between these two extreme opinions it seems to us that a middle view will more nearly correspond with the facts, and with the subsequent conduct of Galileo and his enemies. We accept Professor Favaro's view, but with this qualification, that the document is true to the letter, but not to the spirit of the proceedings of 26th February. To our mind the admonition by the Cardinal was all that was intended (see documents above, dated 3rd March and 26th May). The further interference of the Commissary-General was due to *trôp de zele*, or fussiness, on his part, and may have arisen in this way. Imagine the case of a culprit brought up for sentence on his first offence before a magistrate and a fussy or over-zealous clerk. The culprit, expecting (as we know

Galileo did) something very mild, is surprised at being admonished to abandon his opinions; he gives expression to this surprise by word or look —seems not to comprehend. "What," he then exclaims, "must I abandon them altogether? Can I not even dis——" "No, no," cuts in the clerk. "You are commanded to abstain altogether from teaching or defending, and even from discussing them in any way whatever, and if you do not acquiesce you will be imprisoned." The culprit, amazed, says no more, bows, and retires crestfallen, noting only the Cardinal's admonition, and disregarding the Commissary's remark altogether, or regarding it as no part of the decision, as merely a repetition in other and stronger words of the Cardinal's simple admonition.

That this is the view which Cardinal Bellarmine and the Holy Office took of the proceedings is clear from the wording of the documents dated 26th May and 3rd March, in which the interpolation of the Commissary-General is ignored; and that it is the view which Galileo took, his after conduct will show. Then, the facts that his writings are not mentioned in the decree of 5th March, and that the book of Copernicus is only suspended pending correction, go to show that the Copernican doctrines might still be held and discussed in a hypothetical way, and by Galileo as well as by others. In fact, it was so understood at the time, and the trivial alterations afterwards made in the book of Copernicus (as above stated) confirmed this idea.[1]

Galileo having taken his admonition was ad-

[1] See more on this subject p. 275 *infra*.

mitted to an audience of the Pope, Paul V., on 11th March, which lasted three-quarters of an hour. He took occasion to refer to the events just concluded, and expressed his fears of never-ending persecution; but Paul V. consoled him with the assurance that he need have no fear; that he was held in so much esteem by himself and the whole Congregation, that they would not listen to any calumnies; and that, as long as he occupied the chair of St. Peter, Galileo might rest assured that he was safe from all danger.

On the eve of Galileo's departure from Rome, Cardinal del Monte wrote to the Grand Duke "to bear witness that he was leaving with the best reputation, and the approval of all who have had transactions with him, for it has been made manifest how unjust have been the calumnies of his enemies."[1] However, the Grand Duke's Ambassador, Guicciardini, told a different story, and, perhaps, a truer one. All along he had tried to get Galileo recalled to Florence; his last letter of 13th May may be cited as a specimen of his previous despatches.

"Galileo," he says, "seems disposed to emulate the monks in obstinacy, and to contend with personages whom you cannot attack without ruin to yourself. It may any moment be heard in Florence that he has stumbled into some abyss or other. However, the heat will probably drive him from Rome before long, and that will be the best thing that can happen to him."

Cosimo II., alarmed by these gloomy reports

[1] The letter is dated 4th June 1616.

of his ambassador, at last issued orders for Galileo's return, and on 23rd May Picchena wrote :—

"You have had enough of monkish persecutions and ought to know by this what the flavour of them is. His Highness fears that your longer stay in Rome may involve you in fresh difficulties, and would therefore be glad if (as you have so far come honourably out of the affair) you would not tease the sleeping dog any more, and would return here as soon as possible. There are rumours flying about which we do not like, and the monks are all powerful. I, your servant, must not fail to warn you, and to inform you, as in duty bound, of the wishes of our Master, wherewith I kiss your hand."

Galileo complied with this order with the least possible delay, and set out on his homeward journey on 4th June 1616.

Amidst all the cares and worries of this visit Galileo's teeming mind was busy, as always, with abstruse questions of science. He had not been many days in Rome when a suggestion from Cardinal Orsini was enough to start him on a treatise on the Flux and Reflux of the Tides, written, as was customary in those days, in the form of a letter to the Cardinal, and dated 8th January 1616. We have seen from his letter to Vinta, of 7th May 1610, in which he enumerates his contemplated works, that a treatise on the Tides was one of them. Galileo's theory is that the tides are the visible effects of the terrestrial double movement, since they are the combined result of (1) the earth's daily rotation, and (2) the inequality of the absolute velocities through space of the various parts of the

earth's surface. We now know this to be erroneous, but it required a farther advance in the science of motion than had been obtained even at a much later date to point out its insufficiency.

The problem of the tides had been from the earliest ages one of the most difficult, and the solutions advanced by different enquirers show that it long deserved the name given to it—"the grave of human curiosity." Some supposed the rise of the waters to be due to the influx of rivers into the sea; others compared the earth to a huge animal, whose respiration caused the tides; a third theory supposed the existence of subterraneous fires which periodically made the sea to boil up; while others again attributed this boiling effect to changes of temperature in the sun and moon, or to variations in the amount of their light.

Galileo's ideas on the subject are given at great length in his treatise, and are developed and re-inforced in his Dialogues on the Two Systems of the World, where they occupy the whole of the fourth "Day."

Almost as soon as he had discovered the moons of Jupiter in 1610, Galileo began a work the difficulty and fatigue of which he has himself indicated by comparing it with the labours of Atlas. It was a series of observations on the satellites with a view of drawing up tables so as to be able to predict all particulars of their situations, relations, and eclipses; and thus to have the means of determining at any hour of the night the longitude of the place of observation. In the midst of his numerous occupations and annoyances of all

sorts, he steadily worked at this laborious task.[1]

After six years' observation and calculation of Jupiter's satellites, and confident of the practicability of his method, Galileo in 1616 opened a correspondence on the subject with the Court of Spain.[2] The reader will understand how the satellites were to be used, if their movements could be so nicely ascertained as to enable Galileo at Florence to predict the exact times at which any remarkable configurations, such as an eclipse, would occur. A mariner, who should observe the same eclipse and compare the local time (which he might know by setting his watch by the sun on the previous noon) with the time mentioned in the tables, would, from the difference between the two, have data for calculating his position. Thus, as the earth rotates through 360° of longitude in 24 hours, or 15° per hour, the difference between the two times multiplied

[1] A ready method of finding longitudes at sea had long been an object of search with all the maritime powers of Europe. In 1598 the Spanish Government offered a prize of 1000 crowns for the discovery of such a method. The Dutch followed the example of Philip III. of Spain; the French Government followed with a prize of 100,000 livres; and the French Academy established an annual prize for those who made the most useful discoveries connected with the subject. In 1714 the English Parliament appointed a committee to consider the question, when an Act was passed granting £10,000 for a method of finding the longitude to a degree, or 60 geographical miles; £15,000, to 40 miles; and £20,000, to 30 miles. At length, in 1736, the problem was solved in the ship's chronometer of John Harrison, a village carpenter of Faulby, Yorkshire, which did not vary two minutes in the course of a year.

[2] In 1612 Galileo first announced his method to the Spanish Government, through the medium of the Tuscan Ambassador, but no details or explanations were then given.

by 15 will give the degrees of longitude by which the ship is distant from the meridian of Florence.

Our moon had already been used for the same purpose; it changes its position amongst the stars continuously, and if at specified times throughout the day that position can be predicted, it is available as a signal of the exact time at Florence, or wherever the tables are calculated for. Using his watch as already explained, the mariner would then be able to determine his longitude. But in the beginning of the seventeenth century, tables predicting the position of the moon could only have been very rough. And its very proximity to the earth is a disadvantage; for an observer on the high seas would get a slightly different view of it from that expected at Florence, and this apparent difference in the moon's position amongst the stars, as seen from the two different places, would have to be allowed for.

This complication would be avoided if Jupiter were made use of as a time-recorder instead of the moon. The great distance of Jupiter, the frequency of the eclipses (more than 1000 yearly), and (it was expected) their suddenness, seemed to promise success to Galileo's method. It was, however, beset by practical difficulties. First, there was the difficulty of observing such small objects as Jupiter's moons from the deck of a ship; and secondly and greater, accurate timekeepers were necessary, but were not available; for, although we have just spoken of *watches*,

the watches and clocks of those days were not such as could be relied on even for the few hours between the time of observing the sun at noon and the subsequent observation of Jupiter.

Galileo thoroughly appreciated these difficulties, and to obviate the first he proposed to use a binocular telescope with a magnifying power of 10 diameters. This he called the *Celatone* or *Testiera*, as the apparatus resembled a diving-helmet with telescopes fixed in the apertures for the eyes.[1] He also had made in the arsenal at Pisa a kind of boat or chair, floating in another boat filled with water or oil, in which the observer would be protected from all motion.[2] To remedy the second difficulty he had hopes of utilising his early observations on the pendulum and applying it as a measurer of time. But it was many years

[1] The above reference to the *Celatone* is based on a letter of Galileo to Orso d'Elci, without date but *circa* June 1617. The passage is vague and evidently with a purpose, as he wished the "invention" to be kept secret. Professor Favaro has since drawn my attention to another of Galileo's letters, dated 6th June 1637, in which we find the apparatus for the first time clearly described. "I made," he says, "for the use of our navy a kind of cap, fitted to the head of the observer, and supporting a telescope in such a way that it always points in the same direction as the free eye, so that an object viewed by the latter is also seen by the other eye through the telescope. A similar apparatus could be made and fixed on the shoulders and chest of the observer, to support a telescope of a power sufficient to show the satellites of Jupiter, and adjustable as in the case of the *Celatone*. When, then, the free eye is turned towards Jupiter the other eye sees through the telescope not only the planet but its satellites." From this it is clear that Galileo did not propose a *binocular* telescope as has hitherto been supposed, but simply a new way of using an ordinary one.

[2] Galileo's letter to Picchena, 22nd March 1617. In this way he is said to have made satisfactory observations in the harbour of Leghorn, while the ship was tossed about by a strong wind.

later before steps were taken to give his ideas a practical form.

During his visit to Rome (in 1616) Galileo disclosed his longitude proposals to the Conte di Lemos, the Spanish Viceroy of Naples, who had been President of the Council of the Spanish Indies, and was fully aware of the importance of the matter. Negotiations were opened with the Spanish Minister at Rome, and the Grand Duke of Tuscany, Cosimo II., instructed his ambassador at Madrid to conduct the business with the Spanish Court. Galileo entered warmly into these negotiations, as may be gathered from the following extract from a letter to the Tuscan Minister in Spain.

"Your Excellency may well believe that if this were an undertaking which I could conclude by myself, I would never have gone about begging favours from others. But in my study there are neither seas, nor Indies, nor islands, ports, shoals, and ships, for which reason I am compelled to share the enterprise with great personages, and to fatigue myself to procure the acceptance of that which ought with eagerness to be asked of me. But I console myself with the reflection that I am not singular in this, since it commonly happens that, with the exception of a little reputation (and that too often obscured and blackened by envy), the least part of the advantage falls to the share of inventors of things which bring gain (in honours and riches) to others. However, I will never cease to do everything in my power to forward this matter. I am ready to leave here all my comforts, country, family, friends, and to cross over into

Spain, to stay as long as I may be wanted in Seville, or Lisbon, or wherever it may be convenient, in order to implant the knowledge of my method, provided only that due assistance and diligence be not wanting on the part of those who are to receive it."

But he could not, with all his enthusiasm, bring the Spanish Court to a decision. His proposals were discussed in Council, favourable reports were made to the King, but his Majesty could not make up his mind to spend money on experiments which he thought might prove as fallacious as others that had been tried before with the same object. The negotiation dragged on during 1617 and part of 1618 and then languished, and, although occasionally renewed during the next ten or twelve years (in 1620, 1629, and 1632), was never brought to a satisfactory issue.

Galileo's disappointment was in some degree mitigated later on by his own Sovereign taking up the method for use in the Tuscan Navy. Its application, however, has proved to be beset with so many difficulties that the method has fallen into disuse. The unsteadiness of the observer at sea cannot be overcome, and is more serious in an observation of the required nature than in the measurement of the moon's distance from a star. Accordingly the method is now one of historic interest only.

# CHAPTER IX

## GALILEO IN FLORENCE

### 1617-1624

FOR a long time after his return to Florence in June 1616, Galileo's health had been very indifferent. A complication of his old maladies, aggravated by long fits of hypochondria, left him little time or taste for work, and sadly interrupted his correspondence. His old friend Sagredo often advised him to take his ease and be content with the laurels he had already won. "Philosophise," he used to say, "comfortably in your bed and leave the stars alone. Let fools be fools, let the ignorant plume themselves on their ignorance. Why should you court martyrdom for the sake of winning them from their folly? It is not given to every one to be of the number of the elect. I believe the universe was made for my service, not I for the universe. Live as I do and you will be happy." This, indeed, was the burden of Sagredo's letters from the time his friend quitted Padua in 1610 up to his own death on 5th March 1620.

But Galileo had not the epicurean temperament of his friend. Speculation and experiment were as necessary to him as food and air; yet from these

he was now practically debarred by the Papal prohibition of 26th February. How could he resume his old work, or begin any new one? The Copernican theory of the world was the basis of all his work. Its acceptance and application were forbidden him, and the general permission to employ it as a working hypothesis was a mockery. Can we wonder then at the fits of melancholy which frequently oppressed him. Yet inaction to a man of his temperament was intolerable; he must be doing something; he was fond of gardening, but he could not be always digging, and weeding, and pruning. He must be doing something else; he could not write for publication, but he could at least commune with his intimate friends; and so, for some years he poured out his thoughts in long private letters, copies of which were circulated amongst the learned men of Europe. Unfortunately, few of these are now extant; but amongst these few there is one which deserves notice, as it shows how intolerable the writer felt his position to be. It is also interesting as a specimen of the keen sarcasm of which he was a master. During his stay at Rome, as we have seen, he wrote a treatise on the tides. Now, on 23rd May 1618, he sent a copy of this to the Archduke Leopold of Austria; but as since it was written the proceedings culminating in the decree of 5th March 1616 had taken place, Galileo added the following accompaniment:—

"With this I send a treatise on the causes of the tides, which I wrote more than two years ago, at the suggestion of his Reverence Cardinal Orsini in Rome, and at the time when the theologians

were thinking of prohibiting the book of Copernicus and the doctrine enunciated therein of the motion of the earth, which I held to be true until it pleased those gentlemen to prohibit the work and to declare that opinion to be false and contrary to Scripture. Now, knowing as I do that it behoves us to obey the decisions of the authorities and to believe them, since they are guided by a higher insight than any to which my humble mind can of itself attain, I consider this treatise which I send you merely to be a poetical conceit or a dream, and desire that your Highness may take it as such, inasmuch as it is based on the double motion of the earth, and, indeed, contains one of the arguments which I have adduced in confirmation of it. But even poets sometimes attach a value to one or other of their fantasies, and I likewise attach some value to this fancy of mine. Now, having written this treatise and having shown it to the Cardinal above mentioned and a few others, I have also let a few exalted personages have copies, in order that, in case any one not belonging to our Church should try to appropriate my curious fancy (as has happened to me with many of my discoveries), these personages, being above all suspicion, may be able to bear witness that it was I who first dreamed of this chimera. What I now send is but a fugitive performance. It was written in haste and in the expectation that the work of Copernicus would not be condemned as erroneous eighty years after its publication. I had intended at my convenience and in quiet to have gone more particularly into this subject, to have added more proofs, to have arranged the whole anew, and to have put it into a better form. But a voice from heaven has aroused me and dissolved all my confused and tangled fantasies in mist! May therefore your Highness graciously accept it, ill-arranged as it is;

and if Divine love ever grants that I may be in a position to exert myself a little, your Highness may expect something more solid and real from me."

In August 1618, three comets appeared in the heavens, and the brilliant one in the constellation of the Scorpion — one of the most splendid of modern times — especially attracted the attention of astronomers. Although this was visible until January 1619, Galileo had little opportunity of observing it, as he was confined to bed nearly the whole time by severe illness.[1] However, we may suppose with Viviani that he was able to observe a little, but, certainly, he reflected much, and, as soon as he was able, he communicated his views to his friends, amongst others to the above-mentioned Archduke Leopold, who, being in Florence on a visit, came to see him.

His views were published about the middle of 1619, through the medium of Mario Guiducci, a Florentine disciple.[2] He did not consider comets to be really heavenly bodies, analogous to the planets as was currently supposed, but only atmospheric phenomena—columns of vapour which rise from the earth to a great height, far beyond the moon, and become temporarily visible by refraction of the sun's rays. In fact, he classed comets in the same category as rainbows and mock suns. Referring to some proposed parallax measurements of the comets,

[1] During great part of the years 1617 and 1618, Galileo was ill or ailing. In June 1618 he made a pilgrimage to Loreto, "The Mecca of Christendom," in the hope that a change of air and habits might free him from the fevers which molested him.

[2] "Discorso delle Comete di Mario Guiducci," etc., Florence, 1619.

he pointed out the difference in this respect between a fixed object, the distance of which may be calculated by two angular observations at a known distance apart, and atmospheric appearances like rainbows which are simultaneously formed in different drops of water for each spectator, so that two observers in different places are, in fact, viewing different objects. He then warns astronomers not to engage with too much warmth in a discussion on the distance of comets before they assure themselves to which of these two classes of phenomena they are to be referred. The remark is in itself perfectly just, although the opinion which occasioned it is now known to be erroneous; but it is questionable whether the few observations which up to that time had been made upon comets were sufficient to justify the bitter censures which have been cast on Galileo on account of it. Indeed, the same opinion was held for a time by Cassini, the celebrated astronomer of the Paris Observatory, many years *after* Galileo, and when the science was considerably more advanced; and even Newton did not consider it beneath notice, for in his "Principia" he takes pains to show on what grounds it is untenable.

In the course of Guiducci's essay, some opinions of the Jesuit father, Orazio Grassi (in a public discussion on the comets at the Collegio Romano), were so indiscreetly attacked as to raise the ire of the whole Jesuit's College at Rome. Grassi, under the pseudonym of Lotario Sarsi, published

an onslaught on Galileo's cometary theory in a book called "The Astronomical and Philosophical Balance" (1619)—a violent pamphlet full of abuse of Galileo and his school.[1] Friends, like Prince Cesi, and Mgrs. Ciampoli and Cesarini, now advised that the master himself should take up the fight; but ill-health and caution, owing to the troubled state of the religious and political horizons, prevented the appearance of his reply for three years. At length, in October 1622, he sent the MS. of this celebrated work, "Il Saggiatore" (The Assayer), to Mgr. Cesarini in Rome, and for five months it passed from hand to hand among the members of the Accademia dei Lincei, who examined it carefully and (with the author's consent) altered some passages which might possibly have given a handle to his enemies. The Papal *Imprimatur* was granted 2nd February 1623, on the report of Father Niccolò Riccardi, Examiner, who was formerly a pupil of Galileo, and of whom we shall hear a great deal in the sequel. This report was as follows:—

"By command of the Master of the Palace, I have read the work 'Il Saggiatore,' and not only have I detected nothing in it which is contrary

[1] The reader will have observed that, so far, hardly one of Galileo's discoveries, or of his published opinions, whether correct or incorrect, has wanted antagonists and detractors; and so we shall find it to the end. The case is probably unique in history, and rightly did Byron sing of "The starry Galileo with his Woes," for never was a man so persecuted for fifty out of the seventy-eight years of his busy life. A French biographer (Parchappe) justly laments "the loss to science in the enormous expenditure of energy and time consumed in defending himself and his teaching against the incredible rage of his enemies in struggles without end." "Galilée, sa Vie," etc., Paris, 1866, p. 79.

to good morals, or deviates from the Divine Truth of our religion, but I have found in it such beautiful and manifold observations on natural philosophy that I think our age will not have to boast merely of having been the inheritor of the labours of earlier philosophers, but also of having been the discoverer of many secrets of nature which they were not able to penetrate, thanks to the subtle and solid researches of the author whose contemporary I think myself happy to be."

While the work was in the press, an event occurred which seemed likely to produce a change for the better in Galileo's relations with Rome. On 8th July 1623, Gregory XV. succumbed to age and infirmity in the second year of his pontificate; and the man, who at the age of fifty-five succeeded him (elected 8th August 1623), was Cardinal Maffeo Barberini, now Pope Urban VIII. Galileo placed great hopes for the progress of science in general, and for, at least, toleration of the Copernican doctrine, on this election; and to all appearances he was justified in doing so. Not only was Urban VIII. a refreshing contrast to his immediate predecessors who cared little for art or science, but, as Cardinal, he had for many years entertained a great friendship for Galileo, as many letters of his still extant show. Thus, writing from Bologna, 5th June 1612, on receipt of a copy of the work on Floating Bodies, he says:—

"I have received your treatise on various scientific questions which have been raised during my stay here, and shall read them with great pleasure, both to confirm myself in my opinions

which agree with yours, and to enjoy with the rest of the world the fruits of your rare intellect."

Another letter of 20th April 1613, after the work on Sun-spots had appeared, may be quoted :—

"Your printed letters to Welser have reached me, and are very welcome. I shall not fail to read them with pleasure again and again as they deserve. This is not a book which will be allowed to stand idly among others. It is the only one which can induce me to withdraw for a few hours from my official duties to devote myself to its perusal, and to the observation of the planets of which it treats—if the telescopes we have here are fit for it. Meanwhile I thank you very much for your remembrance of me, and beg you not to forget the high opinion which I entertain for a mind so extraordinarily gifted as yours."

The Cardinal had not confined himself to mere assurances of esteem and friendship in his letters, but had shown them in his acts. Thus, in the troublous times in 1615-16, his influence with Pope Paul V. greatly helped Galileo to extricate himself from his difficulties.

In 1620, Barberini gave another and a really enthusiastic proof of his regard. He celebrated Galileo's discoveries in some elegant verses (in which astronomy was allied with morality) and sent them with the following letter, dated 28th August :—

"The esteem, which I always entertain for yourself and for your great merits, has given occasion to the enclosed verses. If not worthy

of you they will serve at any rate as a proof of my affection; while I purpose to add lustre to my poetry by coupling it with your renowned name. Without wasting words in further apologies, I beg you to receive with favour this small proof of my great esteem."

After much delay in the printing, "Il Saggiatore" appeared at the end of October 1623, with a dedication to Pope Urban VIII., and under the auspices of the Accademia dei Lincei. This celebrated work is a masterpiece of ingenuity, for the author not only dexterously avoids the snares laid for him by Father Grassi and his supporters, but brings defeat and ridicule upon them at every turn. All this is done in so sparkling a style, and the reasoning, and counter refutations are so convincing, that "Il Saggiatore" deserves its reputation as a model of dialectic skill, and an ornament of classical Italian literature.

The book was a great success, and, of course, intensified the bitterness of the Jesuitical party; so much so that the General of the Order forbade, under severe penalties, the members to speak of it even among themselves. It is important to note that the Pope was delighted with it, and had it read aloud to him at table.

Early in 1625, the book was denounced anonymously to the Inquisition as a veiled defence of the Copernican doctrines, and a movement was begun to prohibit it, or, at least, to have it "corrected"; but the attempt failed, and only brought discredit upon the agitators. Father Guevara, General of the Theatines, to whom it

was submitted for examination, reported most favourably of it, and went so far as to say that, even if the doctrine of the earth's motion had been maintained, it would not have appeared to him a sufficient reason for condemning the work.

One or two extracts will be interesting. As a specimen of keen cutting banter the following is admirable. Sarsi had quoted a story from Suidas (in support of his argument that motion always produces heat) to the effect that the Babylonians used to cook their eggs by whirling them in a sling. To this Galileo replied:—

"I cannot refrain from marvelling that Sarsi will persist in proving to me, by authorities, that which at any moment I can bring to the test of experiment. We examine witnesses in things which are doubtful, past, and not permanent, but not in those things which are done in our own presence. If discussing a difficult problem were like carrying a weight, since several horses will carry more sacks of corn than one alone will, I would agree that many reasoners avail more than one; but discoursing is like coursing, and not like carrying, and one barb by himself will run farther than a hundred Friesland horses. When Sarsi brings up such a multitude of authors, it does not seem to me that he in the least degree strengthens his own conclusions, but he ennobles the cause of Signor Mario and myself, by showing that we reason better than many men of established reputation. If Sarsi insists that I must believe, on Suidas's credit, that the Babylonians cooked eggs by swiftly whirling them in a sling, I will believe it; but I must say, that the cause of such an effect is very remote from that to which it is

attributed, and to find the true cause I shall reason thus. If an effect does not follow with us which followed with others at another time, it is because, in our experiment, something is wanting which was the cause of the former success; and if only one thing is wanting to us, that one thing is the true cause. Now we have eggs, and slings, and strong men to whirl them, and yet they will not become cooked; nay, if they were hot at first they more quickly become cold; and since nothing is wanting to us but to be Babylonians, it follows that being Babylonians is the true cause why the eggs became cooked, and not the friction of the air, which is what I wish to prove. Is it possible that in travelling post, Sarsi has never noticed what freshness is occasioned on the face by the continual change of air? and if he has felt it, will he rather trust the relation by others of what was done two thousand years ago at Babylon, than what he can at this moment verify in his own person? I, at least, will not be so wilfully wrong, and so ungrateful to nature and to God, that having been gifted with sense and language I should voluntarily set less value on such great endowments than on the fallacies of a fellow-man, and blindly and blunderingly believe whatever I hear, and barter the freedom of my intellect for slavery to one as liable to error as myself."

Our next extract is a good sample of Galileo's metaphysics, in which may be observed the germ of a theory closely allied to that which was afterwards developed by Locke and Berkeley.

"I have now only to fulfil my promise of declaring my opinions on the proposition that motion is the cause of heat, and to explain in what manner it appears to me that it may be true. But I must first

make some remarks on that which we call heat, since I strongly suspect that a notion of it prevails which is very remote from the truth; for it is believed that there is a true accident, affection, or quality, really inherent in the substance by which we feel ourselves heated. This much I have to say, that as soon as I form a conception of a material or corporeal substance, I simultaneously feel the necessity of conceiving that it has its boundaries, and is of some shape or other; that, relatively to others, it is great or small; that it is in this or that place, in this or that time; that it is in motion, or at rest; that it touches, or does not touch another body; that it is unique, rare, or common; nor can I, by any act of the imagination, disjoin it from these qualities; but I do not find myself absolutely compelled to apprehend it as necessarily accompanied by such conditions as that it must be white or red, bitter or sweet, sonorous or silent, smelling sweetly or disagreeably; and if the senses had not pointed out these qualities, it is probable that language and imagination alone could never have arrived at them. Therefore, I am inclined to think that these tastes, smells, colours, etc., with regard to the object in which they appear to reside, are nothing more than mere names, and exist only in the sensitive body; insomuch that when the living creature is removed all these qualities are carried off and annihilated; although we have imposed particular names upon them (different from those other and real accidents), and would fain persuade ourselves that they truly and in fact exist. But I do not believe that there exists anything in external bodies for exciting tastes, smells, and sounds, but size, shape, quantity, and motion, swift or slow; and if ears, tongues, and noses were removed, I am of opinion that shape, quantity, and motion would remain, but there would be an end of smells, tastes, and sounds, which,

abstractedly from the living creature, I take to be mere words."

As we are now approaching the great crisis of Galileo's public life, it will be convenient to pause and take a glance at his family affairs. We have seen (p. 73) that he was never married, but that he had by the Venetian, Marina Gamba, three children —Virginia, Livia, and Vincenzio. These children were brought up with the mother in Padua, and in a separate establishment from that occupied by the father in Via Vignali.

It would appear that when Galileo quitted Padua in the autumn of 1610, he took the two girls with him to Florence, and placed them under the care of his brother-in-law, Landucci; Vincenzio, being then only four years old, was left behind with his mother until October 1612, when he too was brought to Florence. Shortly afterwards, Marina married a well-to-do man in her own sphere, one Giovanni Bartoluzzi. This step appears to have been taken with Galileo's approval, judging from the respectful and friendly tone of the only letter of Bartoluzzi (17th August 1619) found amongst Galileo's papers. It appears from this letter, and from two others written by Liceti, 31st December 1610, and Pignoria, 25th January 1613, that Galileo behaved with great liberality to Marina and her husband.

In March 1610, before his final departure from Padua, he had the intention of placing his elder daughter as a boarder in the convent of the Nunziatina, Florence; but, although all the preliminaries were settled, the project, for some unknown reason,

was not carried out. What to do with the girls was now become a serious question. Their taint of birth was in painful contrast to the honoured name of his own noble family, as his mother, in her frequent and "terrible" tempers, did not fail to remind him. His means, generally as we have seen insufficient for his wants and never too large, did not hold out the hope of being able to make them independent, or to settle them suitably in marriage. In these circumstances he resolved, while they were yet young, and before they could acquire a taste for the world, to place them both in a convent for life. In November 1611, he took steps to carry out this resolution, but met with many difficulties. He did not wish that the children should be separated, but there was a strict rule against sisters taking the veil in the same convent. Then, there was the further difficulty of the girls being much under the canonical age of full sixteen —Virginia, the elder, being only eleven. However, after long negotiations, and finally through the influence of Cardinal Bandini, the necessary licences were obtained, and in October 1613 the two girls were placed in the Convent of San Matteo, Arcetri, near Florence, as a preparatory step to their novitiate and final profession. In July 1614 they were entered as novices of the Order. The Mother Abbess of the time was a sister of the Secretary Vinta, whose name has often occurred in these pages. From the first the good Lodovica Vinta took a kindly interest in the poor children; and at her suggestion the feasting usual on taking the veil was dispensed with. "It would be better," she said,

"in every way for the ceremony to take place quietly, and the money will be far better employed in adding to the girls' little comforts in the convent than in regaling friends and relations." Finally, Virginia became a professed nun on 4th October 1616, under the name of Suor Maria Celeste; and Livia on 28th October 1617, under the name of Suor Arcangela; and here we shall leave them for awhile.

After the death of Filippo Salviati, on 22nd March 1614, Galileo appears to have given up the villa near Signa, and to have had no settled home of his own for the next three years. He probably had a *pied-à-terre* in his mother's house, where, owing to her terrible tempers and his own frequent illnesses, his lot was not a happy one.

On 15th August 1617, he rented the villa of Lorenzo Segni on the Bellosguardo Hill outside Florence, and here he lived for the next fourteen years. Perched upon a hill it commanded most lovely views of the city and the silvery Arno at its foot, with the far-famed Fiesole beyond, and of beautiful country all round.

"From Tuscan Bellosguardo,
Where Galileo stood at nights to take
The vision of the stars, we have found it hard,
Gazing upon the earth and heavens, to make
A choice of beauty."

—ELIZ. B. BROWNING.

Two hundred years after, the villa was for a time (*circa* 1810) the residence of another famous Italian, Ugo Foscolo, the poet and patriot-soldier of the stirring times in Italy during the Napoleonic period. In 1835, the then owner, Amerigo degli

Albizzi, erected on the north-west front of the house two white marble tablets (each surmounted by a white marble bust) with long inscriptions commemorative of these two great men. The bust of our philosopher, showing well his peculiar nose, is the work of the Florentine sculptor Emilio Demi; and the inscription is from the pen of Vincenzio Antinori, then Director of the Museum of Natural History, Florence.[1]

For nearly seven years after taking the veil we lose sight of Galileo's daughters. We left them as children of sixteen; we are now to meet them as women. Sister Arcangela, the younger, we shall not like; but Virginia, or Sister Maria Celeste, as we must henceforth call her, we shall learn to love. All we know of this charming personality is told in her letters to her father. The first is dated 10th May 1623, but Professor Favaro thinks there must have been many previous ones which are now lost. However this may be, those that remain, one hundred and twenty-four in number, show that there was a close intimacy and affection between father and daughter, and that these relations grew in intensity with the daughter's maturing years. If they did not write they must have often met, for Galileo's house at Bellosguardo was a pleasant half-hour's walk along a charming road from the convent of San

[1] For the inscription see Albèri's ed. of Galileo's works, vol. xv. p. 394. The house is now known as Villa l'Ombrellino, and is occupied by the Russian General, Alexis Zouboff, who kindly allows visitors to see these interesting memorials. The villa is entered from the Piazza Bellosguardo, where one sees on a house in front a marble slab intimating that Garibaldi and Mario lived there.

Matteo. In no other way than on the supposition of a previous intimacy of a close personal kind can we account for the affection which bursts forth in the first letter we possess, and overflows through all of them to the end. This affection must have been, as indeed we shall see it was, a great comfort and consolation to Galileo, sorely tried as he was by frequent illness, by the worries and ingratitude of all the rest of his family, and by the persecution of the outside world.

His letters to his daughter, though we know that she kept them, and was in the habit of re-reading them during such leisure moments as her duties left to her, have unfortunately disappeared. It is probable that these letters so treasured by the daughter were destroyed at her death, lest the convent should be compromised by their presence among its archives—an action which, however much we may regret it, we cannot blame, as we must remember that when Maria Celeste died in 1634 her father was a prisoner of the Inquisition, vehemently suspected of heresy.

We can, however, generally guess the contents of these lost letters, by the answers, which, thanks to her father's loving care, have been preserved to us. In these, Sister Maria Celeste emerges from behind the convent grating; she lifts the veil which envelops her, and shows us a woman's heart full of filial tenderness, of self-abasement, and of interest in some things of that world she had renounced in her childhood. We see this heart of hers often pierced with sorrow, and always

divided between love and fear—love for her father, and fear of impending evil to him.

Besides the father-worship which glows in every page, these letters bear evidence throughout of sound sense and sober judgment, joined to a simple piety. There is not a trace of mysticism in them; there is no mention of minute practices of devotion; she does not pass her nights in the chapel, kneeling on cold stones and expecting visions; she goes to bed like a sensible woman, and takes her seven hours' sleep; she regrets sometimes that her constitution should require so much sleep, but only because she would like better to sit up and write long letters to her "Dearest Lord and Father." Of her Heavenly Father she discourses much; of the Virgin seldom; and we hear of no patron saint. The nuns, she tells us, have each their patron saint—their *Devoto* to whom they tell all their little joys and sorrows; but *she* has her father to confide in and therefore wants no *Devoto*.

Around this loving and lovable nun the other sisters stand—a group of shadows with a name attached to each. Some flit by, once mentioned—sisters these, but not friends; a few come before us more often, Sister Luisa Bocchineri in particular, who was Maria Celeste's bosom friend, and a sister of her brother Vincenzio's future wife. Her own sister Livia appears as little more than a shadow, and what we see of her inclines us, perhaps, to some pity, but to little love. Her disposition seems to have been decidedly selfish, and her sister had to give up to her a great deal for the sake of peace.

"As Sister Arcangela's disposition," she writes, "is very different from mine, being rather odd and whimsical, it is better for me to give up to her in many things, in order to preserve that peace and unity which accord with the exceeding love we bear each other."

We further learn that Arcangela was subject to frequent fits of hypochondria, and that she was constantly ailing. Indeed, ill-health seemed to be more the rule than the exception at San Matteo. Maria Celeste herself was far from being always well; sometimes she, sometimes another sister, sometimes half the convent was down with fever; and rheumatism was frequently complained of.

For the next ten years of Galileo's life and the rest of her own (1623-34), we shall be constantly in touch with this exquisite woman, in extracts from her letters, and the more we see of her the more we shall love her.[1]

On the election of Cardinal Barberini to the Papacy as Urban VIII., Galileo conceived the idea of going to Rome to offer his congratulations in person, and to use his influence with the new Pope to obtain, at least, toleration for the Copernican doctrines, now no longer opposed by the weighty influence of Cardinal Bellarmine, who had died two years before. Remembering the warmth of Barberini's letters while Cardinal, Galileo had reason to hope from a Pontiff so enlightened at

[1] We can only give extracts from a few of these letters. The reader will find them more fully reported in Mrs Olney's "Private Life of Galileo"; while to those who can read them in the original we recommend Professor Favaro's "Galileo e Suor Maria Celeste," Florence, 1891, where all the letters are given in full.

least this much; while as regarded himself, he felt that he must have permission to teach the new astronomical doctrines, not merely as hypotheses but as actual truths, now or never; and according as his desire was fulfilled or not, so would his life-work be complete or incomplete.

Knowing her father to be an object of animosity in so many quarters, the accession of Urban VIII. was a cause of great rejoicing to Maria Celeste, and having been favoured with a sight of the Pope's letters when Cardinal to Galileo, she wrote 10th August 1623, when returning them, in a strain of eagerness:—

"I cannot describe the pleasure with which I perused the letters of the illustrious Cardinal, who is now our Pope, knowing as I do how greatly he loves and esteems you. I have read the letters several times, and now send them back as requested, having shown them to no one except Sister Arcangela, who is also much delighted to see how greatly you are favoured by such an exalted personage. May the Lord give you health to fulfil your desire of visiting his Holiness, so that you may enjoy a still greater measure of his favour. Seeing how many promises he makes in these letters, we hope that you will easily get something to help our brother.[1] I imagine that by this time you will have written a beautiful letter to his Holiness to congratulate him, and as I feel

[1] Vincenzio. Nothing is known of the youth of Galileo's son. In the first years after his arrival in Florence in 1612, he probably lodged with his uncle, Landucci, at least during his father's frequent absences. On 25th June 1619, he was legitimated by Grand-Ducal decree, and not long before the time of Maria Celeste's writing, he was sent to Pisa, under the care of Father Castelli, to study law.

curious about it, I should like very much (if you do not object) to see a copy."

Poor simple soul! She had not perceived the distance between her father, Philosopher and First Mathematician to a Grand Duke, and Maffeo Barberini, the Pope of Rome. Her father must have written at once to enlighten her on the degrees of comparison, for, in her reply of three days later, she confesses her ignorance with touching humility:—

"From your beloved letter I see how little knowledge of the world I must possess to have thought as I did that you would write immediately to such a personage—to one who is, in fact, the head of Christendom. I therefore thank you for the hint you have given me, and feel sure that your love for me will induce you to excuse my ignorance as well as many other faults that I possess. I trust that always warned and reproved by you I may gain in knowledge and discretion.

"Since we are not able to see you in consequence of your lingering indisposition, we must patiently resign ourselves to the Lord's will, Who permits all things for our good.

"I put by carefully the letters you write me daily, and when not engaged with my duties I read them over and over again. This is the greatest pleasure I have; and you may think how glad I am to read the letters you receive from persons who, besides being excellent in themselves, have you in esteem."

A few days after, the convent steward, who had been sent with a message to the villa at Bellosguardo, brought back the alarming news

that Galileo was ill, and in Florence. Fearing that the illness might be more serious than usual, she packed off the steward again to the city to see him, and learn from himself the state of his health. She says in the affectionate little note of which the steward was bearer, that she never regrets being a nun, except when her dear father is ill, because then she would like to be with him. Galileo's illness seems to have been serious, for four days later (21st August) we find her writing again, and sending as an excuse a few biscuits baked in a mould representing a fish. The truth is, as she confesses in her note, she wants the steward to *see* her father, and learn his condition from his own lips, evidently placing little reliance on messages given by those around him. On 28th August she wrote again, expressing her grief at hearing that there was no improvement. She sent him a little present of four plums with the hope that, as they were not in as great perfection as she could wish, he would take the will for the deed. She then goes on to say :—

"Please remember that when you get an answer from those gentlemen in Rome, you have promised me a sight of it. I say nothing of the other letters you promised to send me, as I suppose they are at the villa at Bellosguardo."

By the end of August, Galileo, though still far from well, was able to resume his correspondence, and on returning to his villa he sent her the letters she wished to see, also some thread and other trifles that she wanted.

Feeling his time and strength unequal to the literary demands upon them, he now seems to have begun to utilise his daughter's clear handwriting when he wished to have copies of particular letters or papers. Thus, in a note of this period, returning such a paper, she hopes that he will think the copy well done, as then, perhaps, he will let her copy some more, reminding him that to be occupied in his service is her great pleasure and contentment.

With improving health, Galileo began to think it was time to prepare for his journey to Rome, and he wrote to some of his friends to sound them on the project. To Prince Cesi he wrote, 9th October 1623:—

"I have in my head plans of no small importance for the learned world, and perhaps can never hope for so wonderful a combination of circumstances as the present to ensure their success, at least so far as I am able to conduce to it."

Prince Cesi replied:—

"Under the auspices of this most excellent, learned, and benignant Pontiff, science must flourish. . . . Your arrival will be welcome to his Holiness. He asked me if you were coming, and when, and, in short, seems to love and esteem you more than ever."

Tommaso Rinuccini, to whom Galileo also wrote, replying 20th October, said:—

"I swear to you that nothing pleased his Holiness so much as the mention of your name. After I had been speaking of you for some time, I told him that you had an ardent desire to come

and kiss his toe, if his Holiness would permit it, to which he replied that it would give him great pleasure if it were not inconvenient to you, and if the journey would not be injurious to your health, for great men like you, he said, must spare themselves so that they may live as long as possible."

Mgr. Ciampoli and other friends also wrote in the same confident strain.

These replies, as gratifying as reassuring, Galileo appears to have sent to Maria Celeste for her perusal, as in her letters of October (1623) she refers to them. Amongst a great deal about Arcangela's illnesses, and repairs that she had been making to her father's linen, and her brother's collars she writes (20th October):

"I return the letters you sent me to read. They are so beautiful that my desire to see more of them is greatly increased."

Again, on 29th October, she writes:—

"I leave you to imagine how pleased I am to read the letters you constantly send me. Only to see how your love for me prompts you to let me know fully what favours you receive from these gentlemen is enough to fill me with joy. Nevertheless, I feel it a little hard to hear that you intend leaving home so soon, because I shall have to do without you, and for a long time too, if I am not mistaken. Your lordship may believe that I am speaking the truth when I say that except you there is not a creature who gives me any comfort. But I will not grieve at your departure because of this, for that would be to complain when you had cause for rejoicing. Therefore, I too will

rejoice, and continue to pray God to give you health to make a prosperous journey, so that you may return satisfied, and live long and happily. Although I know it is not necessary for me to do so, yet I recommend our poor brother to your kindness, and I entreat you to forgive him his fault in consideration of his youth, and which, seeing it is the first, merits pardon. I do beg and entreat you to take him to Rome with you, where opportunities will not be wanting to give him that assistance which paternal duty and your natural kindness will prompt you to seek out."

Vincenzio was then seventeen. What the escapade was which brought him into disgrace we are not told. And, unfortunately, this was not the only time that his sister had to intercede for him. In disposition this young man would seem to have resembled his uncle, Michelangelo. Years brought him no discretion. Wayward, selfish, idle, with a great capacity for spending money he had not earned, this only son was a constant thorn in his father's side. Castelli, who looked after him at Pisa with paternal solicitude, even to the buying of his shoes and stockings, had to complain of his mulish obstinacy. A fault confessed was half atoned for, the good Father thought, and he strove hard to bring him to confession, assuring him that no punishment should follow. "But he is as hard as a stone, and one would think he was struck dumb by enchantment. As for me I am in utter despair about him."

Maria Celeste had been busy working at her father's new set of dinner-napkins which had been cut too short, and must have pieces added; and

not having heard from him for nearly a month, she was getting very anxious. On 21st November she wrote:—

"I cannot rest any longer without news, both for the infinite love I bear you, and for fear lest this sudden cold, which generally disagrees so much with you, should have caused a return of your old pains and other complaints. I therefore send the man, who takes the letter purposely, to hear how you are and also when you expect to set out on your journey. . . . As I have no bedroom of my own, Sister Diamante kindly allows me to share hers, depriving herself of the company of her own sister for my sake. But the room is so bitterly cold that, with my head in the state in which it is at present, I do not know how I shall remain, unless you can help me by lending me a set of those white bed-hangings which you will not want now.

"Moreover, I beg you to be so kind as to send me that book of yours which has just been published ['Il Saggiatore'], so that I may read it, for I have a great desire to see it.

"These few cakes I send are some I made a few days ago, intending to give them to you when you came to bid us adieu. As now your departure is not so near as we feared, I send them lest they should get dry.

"Sister Arcangela is still under medical treatment and is much tried by the remedies. I am not well myself, but being so accustomed to ill-health I do not think much of it.

"*P.S.*—You can send us any collars that want getting up."

# CHAPTER X

## FOURTH VISIT TO ROME—RETURN TO FLORENCE

### 1624-1629

LONG delayed, first by illness and then by bad weather, whole tracts of country being under water, Galileo at length set out for Rome 1st April 1624. Reaching Acquasparta on 5th April, he stayed a fortnight with his friend Prince Cesi, and arrived in Rome on the 23rd, provided with a warm letter of recommendation from the Grand Duchess Cristina to her son Cardinal de Medici. From Acquasparta he wrote to his daughter, telling her of the flattering reception he had met with from Prince Cesi, who was able to assure him that his presence in Rome was anxiously awaited "by great personages." On the other hand he was grieved to hear of the sudden death of Mgr. Cesarini, a warm friend whom he had both loved and honoured. This event, as Maria Celeste reminds her father (26th April), "gives food for reflection on the vanity and fallacy of all earthly hopes"; but she timidly adds, "I would not have you think that I write only to sermonise you, therefore I will say no more."

All the world of Rome was aware of the favour

in which the Pope held Galileo. His old friends, therefore, received him with greater delight than ever, and his enemies dared only to clench their fists behind his back. His letters express the great satisfaction which his reception afforded him; but as regarded the object which was nearest his heart he was not so satisfied. Within six weeks he had had six long interviews with Urban VIII., had always been most affably received, and was allowed to bring forward all his arguments in support of the Copernican theory; but all to no purpose; the Pope listened to his arguments, but would not grant his earnest entreaties for, at least, a passive toleration of the new doctrines.

As soon as the Pope's attitude became known, Galileo's clerical friends had to be cautious, and avoided as far as possible all reference to the prohibited doctrines. One of these, Father Niccolò Riccardi, at once took his seat on the fence.

"As to the truth or falsity of the theory," wrote Galileo to Cesi on 8th June, "he accepts neither Ptolemy nor Copernicus, but quiets his soul in a very speedy manner. He sets angels to work at moving the heavenly bodies, and these make them go as they do go (however that may be) without the slightest difficulty or entanglement! Certainly this ought to be enough for us!"

Finding that his efforts to get the decree of 5th March 1616 revoked were of no avail, Galileo resolved with a heavy heart to return home, after a six weeks' stay in Rome. On the eve of his departure, the Pope loaded him with favours which must have seemed to him like mockeries. His

Holiness promised him a pension for his son,[1] and three days after sent a picture for himself; then two medals—one of gold and one of silver, and quite a number of *Agnus Dei!* Not content with these marks of favour, he addressed an official letter (*Breve*) to the Grand Duke, 8th June, in which, to the no small chagrin of Galileo's enemies, his Holiness not only did full justice to our philosopher's services to science, "the fame of which will shine on earth so long as Jupiter and his satellites shine in heaven," but laid special stress on his religious sentiments:—

"We have," he said, "observed in him not only literary distinction, but love of religion, and all good qualities worthy of the Papal favour. When he came to congratulate us on our accession we embraced him affectionately and listened with pleasure to his learned demonstrations, which add fresh renown to Florentine eloquence. We desire that he should not return to his native country without receiving from our generosity manifold proofs of our favour. And that you may fully understand to what extent he is dear to us, we give this honourable testimony to his virtue and piety. And, further, we assure you that we shall thank you for any kindness that you can show him; and by imitating, or even surpassing, our fatherly liberality, you will add to our gratification."

Fruitless as was his journey to Rome as re-

[1] The pension of 60 crowns was granted on 20th March 1627, but owing to the religious exercises attached to it, Vincenzio would not accept it. It was then transferred to a nephew, but as he proved unworthy, it was finally settled on Galileo himself, on 12th February 1630, with an increase of 40 crowns, but with the condition that, as it was derived from ecclesiastical benefices, he should adopt the tonsure—to which he is said to have consented. He drew the pension thus strangely obtained to the end of his life.

garded the grand object of his life—the emancipation of the Copernican theory—Galileo was yet able to do something for the advancement of science. He improved, if he did not invent, the microscope.

The principle of the telescope and the microscope is to the mathematical optician one and the same. The former is merely made to collect parallel rays from distant objects; the latter, diverging rays from near objects. The invention of the one, therefore, could hardly fail to follow immediately upon the other; and accordingly we learn that, very soon after inventing the telescope, Galileo adapted it for the examination of small objects. John Wedderburn, a Scotch student at Padua, in a defence of his master (published in 1610) against the calumnies of Martin Horky (see p. 106 *ante*), states that he heard Galileo describe in what manner he perfectly distinguishes with his telescope the organs of motion and of the senses of the smaller animals, especially in a certain insect, which has each eye covered by a rather thick membrane, which, perforated with seven holes, like the visor of a warrior, allows it sight.

"Here hast thou," he continues, "a new proof that the glass concentrating its rays enlarges the object. In other animals of the same size, and even smaller, some of which have, nevertheless, brighter eyes, these appear only double, with their eyebrows and the other adjacent parts."

In 1614, the Frenchman Tarde, Canon of the Cathedral of Sarlat (Dordogne), was travelling in Italy, and on arriving at Florence called on Galileo,

whom he found ill in bed. Amongst other reports of this meeting Tarde says :—

"Galileo told me that the tube of a telescope for observing the stars is no more than 2 feet in length; but to see well objects, which are very near, and which on account of their small size are hardly visible to the naked eye, the tube must have two or three lengths. He tells me that with this long tube he has seen flies which look as big as a lamb, are covered all over with hair, and have very pointed nails, by means of which they keep themselves up and walk on glass, although hanging feet upwards, by inserting the points of their nails in the pores of the glass."[1]

In "Il Saggiatore" there is a further reference to a telescope arranged so that one can see very near objects very distinctly, even to the most minute particles; and, finally, Viviani, in his "Vita di Galileo," and in the laudatory inscriptions which he placed on the front of his house in Florence[2] in 1693, records as a fact that Galileo presented a microscope to the King of Poland in 1612. All this goes to show that he was well acquainted with the uses of his invention *qua* microscope, and that he did not dwell upon them, or pursue them to greater length, is, no doubt, because his thoughts were wholly absorbed on its perfection as a telescope, and on the glorious field of astronomical discovery which it laid open to him. Certain it is, that for many years he gave the

[1] See Favaro's "Di Giovanni Tarde e di Una Sua Visita a Galileo" (*Bullettino di Bibliografia e di Storia delle Scienze Matematiche e Fisiche*, Rome, July 1887). A diagram of a microscope is reproduced from a contemporary MS. in the National Library, Florence.

[2] Now No. 9 Via San Antonino, formerly Via dell' Amore.

matter little attention—not until his visit to Rome of which we are now speaking, and when he found the microscope discussed as a novelty which nobody could understand.

We have seen in our account of the invention of the telescope that Jansen, the optician of Middleburg, invented a form of microscope about 1590, in which objects were seen inverted. One of these instruments he presented to the Archduke Charles Albert of Austria, who in turn gave it to Cornelius Drebbel, a Dutchman, then living in London. For many years after, the instrument was practically forgotten; but about 1621, Drebbel appears to have resumed its manufacture in London.

In the following year Jacob Kuffler, a relative of Drebbel, brought a specimen to Rome, a present from M. de Peiresc of Paris to one of the Cardinals. From the letter which accompanied it, dated 7th June 1622, we take the following passage:—

"Your Lordship will receive the present letter from the hand of Signor G. Kuffler of Cologne. He will be able to show you an *occhiale* or telescope of a new invention (different from that of Galileo), with which he shows a flea as large as a cricket, and almost of the same shape, with its two arms and the other smaller legs, head, and almost all the body, covered with crusts or scales, like crickets or small shrimps. The little insects which generate in cheese become as large as flies, and are so distinctly discerned that one sees them to have very long legs, a pointed head, and every part of the body quite distinct."

Unfortunately, Kuffler died before he had time

to explain the management of the instrument, and so it remained a mystery. Two years later, after many accidents and delays, two other specimens arrived, also sent by de Peiresc with brief instructions as to their use. Apparently one was little more than a magnifying glass, which it was easy to understand; but of the other and larger, consisting of two glasses, nobody in Rome could make anything, "although they had the help of mathematicians."

It was at this moment that Galileo arrived. The instrument was shown to him, and, as may be imagined, a very brief study told him not only how to use it but how to improve upon it. He at once told his friends that he had himself made a somewhat similar instrument many years previously, "which magnifies things as much as 50,000 times, so that one sees a fly as large as a hen." He quickly made some specimens, showing objects erect, which he sent to his friends, and soon his microscopes were in as great request as his telescopes. Amongst others, he sent one to Prince Cesi, on 23rd September 1624, with the following interesting letter:—

"I send your Excellency a little spy-glass (*occhialino*)[1] for observing at close quarters the smallest objects, which I hope will afford you the same interest and pleasure that it does to myself. I delayed sending it because my first specimens were imperfect by reason of the difficulty in

[1] Galileo usually called the telescope *occhiale* or *cannocchiale*; and now he calls the microscope *occhialino*. The name *telescope* was first suggested by Demisiani in 1612, and *microscope* by Giovanni Faber in April 1625.

fashioning the lenses. The object is placed on a movable circle (at the base of the instrument) which can be turned in such a way as to show successive portions, a single pose being unable to show more than a small part of the whole. As the distance between the lens and the object must be precisely adjusted in order to see things that are in relief, it is necessary to bring the glass nearer to or farther from the object, according to the parts to be examined. Therefore the little tube is made adjustable on its stand or guide. The instrument should be used in a strong light, or even in full sunlight, so as to illuminate the object as much as possible.

"I have examined with the greatest delight a large number of animals, amongst which the bug is most horrible, the gnat and the moth very beautiful. I have also been able to discover how the fly and other little animals are able to walk on window panes and ceilings feet upwards. But your Excellency will now have the opportunity of observing thousands of other details of the most curious kind, of which I shall be glad to have an account. In short, one may contemplate endlessly the grandeur of Nature, how subtilely she works, and with what unspeakable diligence.

"*P.S.*—The little tube is in two pieces, so that you may lengthen it or shorten it at pleasure."[1]

Soon after his return to Florence, Galileo began to draw up a reply to an attack on the Copernican theory which had been addressed to him in 1616 by Francesco Ingoli, then a lawyer at Ravenna, and afterwards secretary of the Propaganda in Rome. Coming at the time of his first encounter

[1] The only relic of these instruments now in existence is preserved in the Tribuna di Galileo, Florence. The lenses are missing.

with the Inquisition, Galileo wisely refrained from answering it then. In 1618 an answer was published from the pen of that other Coryphеus of science, Kepler, in his "Epitome of the Copernican Astronomy,"[1] but Ingoli did not consider himself beaten, and rejoined in a letter addressed to a high official of the Papal Court. Now, after the lapse of eight years, Galileo thought that, protected by the favour of Urban VIII., he might himself venture on a reply; for although there was no hope of a public revocation of the decree of 5th March 1616, he thought, and his correspondents in Rome were of the same opinion, that the prohibition would not be rigidly enforced against him.

In this defence of the Copernican theory, he professes to be actuated by a double motive. On the one hand he wishes to show that, as he had given currency to it before it was condemned by ecclesiastical authority, he had not been the expounder of an improbable or unreasonable theory. On the other hand he wishes to prove to the Protestant Copernicans in Germany that the views of their great countryman had not been rejected in Catholic Italy from a disbelief of their probability, but "from reverence for Holy Scripture, as well as zeal for religion and our holy faith." After this strange introduction, and an assurance that he had no intention of representing the forbidden doctrine *as true*, he proceeds with vigour to refute all Ingoli's objections.

[1] This work was placed on the Index Expurgatorius, 10th March 1619. Galileo had to smuggle a copy into Italy.

In spite of his diplomatic preface, his friends in Rome, aware of the watchfulness of his enemies, advised him not to publish. Galileo wisely gave heed to their warnings, and so the work was only circulated in MS. copies. However, several passages from it were brought under the notice of the Pope by Mgr. Ciampoli, and we learn from a letter of the latter to Galileo, 28th December 1625, that his Holiness highly approved them.[1] This to Galileo and his friends was a hopeful sign. Another was the failure of the agitation undertaken (as already mentioned) in the same year against "Il Saggiatore." Father Grassi ventured, under pretext of a rejoinder to that work, to publish a fresh attack on its author full of spiteful personalities and "arguments" of the most absurd kind. Apparently Grassi, member though he was of the powerful Collegio Romano, could not find a publisher for this work ("Ratio Ponderum Librae") in Rome, and had to bring it out in Paris in 1626, a circumstance which Galileo interpreted as another encouraging sign of the times. Again, in 1624 in a conversation on the subject with the Pope, the Cardinal Zollern (prompted by Galileo) represented that all the heretics of Europe considered the truth of the Copernican doctrine to be beyond doubt, and that, therefore, it would be necessary to be very circumspect in coming to any resolution upon it, to which his Holiness replied that the Church had not con-

[1] In this work Galileo announced that he was preparing a treatise on the Flux and Reflux of the Tides, based on the hypothesis of the double movement of the earth.

demned it; nor was it to be condemned as heretical, but only as rash; and he added, that there was no fear of any one undertaking to prove that it must necessarily be true. These and other indications tended to confirm Galileo in the opinion that, under the pontificate of Urban VIII., the advocates of Copernicanism had little to fear, provided that the defence was so circumspectly handled as not to outrage the oft-mentioned decree of 5th March 1616.

On this assumption (unfortunately a mistaken one, as we shall see) he now, 1626, resolved to carry out the great work which he had long projected, and which, from the vast and varied knowledge it displayed, and from its sparkling and incisive style, was to meet with greater success than had ever been attained by any scientific work. This was his "Dialogue on the Two Principal Systems of the World."

During the next four years, 1626-29, Galileo was almost entirely engaged on the preparation of this great work. His official duties as Philosopher and First Mathematician to the Grand Duke did not take up much of his time, and his scientific correspondence was not considerable[1]; but his work was sadly interrupted by frequently recurring illnesses, and as much so by family troubles of all sorts which sorely tried his patience.

[1] During this period he appears to have written one mathematical treatise bearing the curious title, "On the Estimation of the Value of a Horse." Here may also be noted, though the date is uncertain, his solution of a problem in chances (Sopra le scoperte de i dadi). This was many years before Pascal and Fermat wrote on the same subject.

From the paucity of his daughter's letters during 1625-26, it is certain he often went to see her at the convent. In one written in December 1625 she sends her "dearest Lord and Father" two baked pears, a winter rose from the convent garden, and one of her (frequent) little sermons on the care of his health; in another she sends Christmas greetings, and more collars and cuffs for "our Vincenzio." Sister Arcangela (who is often ill) is better, but still in bed. In a third little note she fears that Vincenzio is angry with her because she delayed sending the new collars he was in want of. Of this young man we learn that he was still pursuing his studies at Pisa, and spending more money than his father could afford. Galileo wrote to Castelli (27th December 1625).

"For the future he is to be content with three crowns a month for pocket-money. With this he can buy plaster figures, pens, paper, or anything he likes, and he may consider himself lucky to have as many crowns as I, at his age, had groats."

During the Carnival season of 1626, Galileo, relieved from attendance on the young Grand Duke,[1] remained closeted at Bellosguardo, absorbed in his Dialogues. Maria Celeste had not seen or heard from him for some time; the Carnival passed and Lent came, but no Galileo. Then she gave vent to her disappointment in

[1] Cosimo II., Galileo's old pupil and good friend, died in 1621. As his heir was then only ten years old, the government was carried on by Cosimo's mother jointly with his widow until 1627, when the son assumed power as Ferdinando II.

words; she is afraid that, in spite of all his past kindness, his love for his daughters must be on the wane, since he has left off coming. This apparently brought him to the convent, and with him came, as a peace-offering, a basket of eatables, rosemary, and citrons. After this, evidently, he was regular in his visits, for only two letters are extant belonging to this period.

In the spring of 1627, Maria Celeste was herself really ill. Self-denying and uncomplaining though she was, the coarse convent food was so unsuitable, that at length she asked for a little money to procure such comforts as were necessary to her recovery, The bread was bad, the wine sour, and the beef uneatable; therefore, if there happens to be a tough old hen in the poultry-yard of the villa, she begs she may have it to make herself some broth.

To the distractions caused by his own chronic ill-health, his daughters' frequent illnesses, and the not very satisfactory reports of his son's conduct at Pisa, were now to be added the worries of his invertebrate brother Michelangelo and his tribe of children.

Since the death of their mother (10th August 1620), the brothers communicated but little, if at all. We have seen that Galileo had no reason to be pleased with his brother's behaviour in money matters; and as long as Michelangelo could rub on without his brother's aid, *he* had no inducement to write. Now, however, it seems to have occurred to him that, after years of a great career, the friend of popes and princes

must be full of riches as well as of honours; the honours might be kept, but as regarded the riches, they ought to be divided amongst the noble family of the Galilei, of which he, Michelangelo, was one, and as good as his brother, though (of course), through no fault of his own, he was less fortunate. If long ago his brother chose to cripple himself for years in order to pay Michelangelo's share as well as his own of their sisters' dowries, that was Galileo's own affair; besides it was many years ago and could not now absolve him from the duty of paying a share of his brother's expenses in the bringing-up of a numerous family (only seven!).

The letter proposing this arrangement is delicious. Writing to Galileo, 5th May 1627, he proposes sending his wife Anna Chiara to act as his brother's housekeeper.

"This arrangement," he says, "would be good for both of us. Your house would be well and faithfully governed, and I should be partly relieved from an expense which I do not know how to meet, for Chiara would take some of the children with her, who would be an amusement for you and a comfort for her. I do not suppose that you would feel the expense of one or two mouths more. At any rate they will not cost you more than those you have about you now, who are not so near akin, and probably not so much in need of help."

In reply Galileo offered to take his brother and his whole family and maintain them 'till Michelangelo should succeed in procuring suitable

employment in Florence. Accordingly, in September, they came to Bellosguardo, a party of eight—the whole tribe, except the eldest daughter left behind with an aunt, who, it is to be hoped, duly appreciated the privilege of supporting her. Early in January 1628, Galileo sent the eldest boy, Vincenzio (nineteen years old) to Rome to study music, and Castelli, who was now settled there as Mathematician to the Pope, kindly took charge of him.

Worn out with mental labour, sleeplessness, and the daily worries of a wild tribe of nephews and nieces, Galileo fell seriously ill again in February 1628, and thinking that the end was near he recalled his son from Pisa, and sent for his brother-in-law Landucci to be reconciled with him.[1]

On hearing of his convalescence, Michelangelo, who had returned to Munich only a few days before Galileo fell ill, wrote (5th April 1628), expressing his joy not so much for his brother's recovery, but "from what I know of our brother-in-law, I tremble to think what would have become of poor Chiara if you had died!" "I think now," he goes on to say, "that with your good leave I shall have all my family back, for I do not wish them to be in danger of suffering unkind treatment one of these days. Meanwhile, I beg that you will

[1] Their relations were never cordial. Besides the old and long-standing quarrel over the payment of the dowry, Galileo had other grievances. Thus, in 1621 Landucci, thinking his merits not properly valued in Florence, quitted his country for a lengthened period and left his wife and family on Galileo's hands. See Favaro's "Galileo e Suor Maria Celeste," pp. 146 and 159.

see to it that your servants pay Chiara proper respect and obedience, as I could on no account suffer her to be maltreated."

The nephew, Vincenzio, had not been many months in Rome when Galileo began to receive reports of his misconduct. Son of his father, vanity, idleness, and impertinence were the least of his failings, and all Castelli's fatherly exhortations were lost upon him. The pension of 60 crowns which Urban VIII. had promised to settle on Galileo's own son was, on his refusal to fulfil the necessary conditions, to be transferred to this nephew, on the same terms, but, wrote Castelli :—

"He has little devotion; my words enter at one ear and go out at the other. He wants to buy a diamond ring, and declares that he is neither monk nor nun, and will have none of my sermons. He is obstinate, impudent, and dissolute, and the insolence of his demeanour is such that I think he must be mad as well as vicious."

While Castelli was writing in this strain, Michelangelo was asking Galileo to pay his son's debts, and complaining that there was no one in all Rome capable of instructing him in the lute.

"Now the dear child will forget all the music he has learnt at Munich."

"If you really mean," he continues in his letter of 8th June, "that there is no remedy to this disorder except my taking the children back again, I must do it, even if I go to Florence on foot. What my troubles are nobody knows. You may say that you too have your own troubles; I believe

you, and I should think that seeing the ruin of these unhappy children should not be the least of them."

He whines about his poverty and the expenses of a house, yet he would not economise by giving it up, because, forsooth, "the discomfort of lodgings would be unbearable." Wines in beer-drinking Munich were a luxury and dear, yet he must have good wine "for his health's sake."

When at last Vincenzio had been sent away from Rome for his misdeeds, Michelangelo requested his brother to keep the young man till he came himself, as he intended to relieve him of the burden of maintaining his family. Galileo had meanwhile endeavoured to procure a page's place for a younger nephew, Alberto, in the Grand Duke's household, but the father objected that "dear Albertino's" tender age (he was born in 1617) made it more proper that he should be served than that he should serve others. It would please him better if his Highness would confer a pension on the boy so that he may stay at home and learn to play on the lute! As for Vincenzio, his conduct was incomprehensible to the father. "But," he says, "I know he did not learn his wicked ways from me or any one else belonging to him. It must have been the fault of his wet-nurse!"

Michelangelo went to Florence in September 1628, and took his family back to Munich, although he had not the wherewith to maintain them, and greatly against the wishes of his brother who was willing to keep them at Bellosguardo. This step

caused our long-suffering philosopher to lose all patience with a man who would only allow himself to be helped in his own way. They parted never to meet again, or even to correspond, for Michelangelo died on 3rd January 1631.

From a letter of Maria Celeste, while these unpleasant matters were tormenting her father, we learn that she too was ill and miserable, jealous, perhaps, of the presence of aunt and cousins in *her* father's house.

"I believe," she wrote 4th March 1628, "that it is possible for paternal love to diminish in consequence of children's ill-behaviour; and this belief is confirmed by some signs which seem to tell me that your affection for us is not so cordial as it was. Besides which, though you are well now, you never, never write me a line. For more than a month I have suffered day and night from headache, and can get no relief.

"I send a letter for Vincenzio, just to remind him of our existence which I think he must have forgotten, seeing that he never writes us a single line."[1]

This last illness of her father caused Maria Celeste the deepest anxiety. Unable to see for herself, she sent the convent steward on one pretext or another to himself see her father and bring her word. The man must have been devoted to this sweet Sister, else we think he would have objected to so many long walks to Bellosguardo, the bearer of such trifles as a

[1] He was at home from Pisa for the Easter vacation. As he had forgotten his sisters' existence we may be sure he was well supplied with collars.

baked quince or a couple of pears, a winter rose, a preserved citron, or a phial of cinnamon water. In one of the affectionate little notes of this period (24th March 1628), she says:—

"Only in one respect does cloister life weigh heavily on me, namely, that it prevents my attending on you personally. My thoughts are always with you and I long to have news of you daily. As you were not able to see the steward the day before yesterday, I send him again to-day with these two pieces of preserved citron as an excuse."

In June 1628, after six years' study of law at Pisa, Galileo's son, then twenty-two years old, took his Doctor's degree, from which, as we know, Galileo himself was debarred more than thirty years before, on account of the expense. His education finished, it was the father's wish that he should seek employment in some branch of the Civil Service of Tuscany, but Vincenzio preferred living an idle life at home, under pretence of aiding his father in his scientific and literary work.

During the summer and autumn of 1628, Galileo's health was so indifferent as to put a stop to all exertion, and, consequently, to his visits to the convent distant over two miles across a hilly road. What little strength he had was reserved for his scientific correspondence and the composition of his Dialogues. But, although Maria Celeste knew this, she was anxious all the same. On 10th December she wrote:—

"You may think from my long silence that

I had forgotten you, just as I might imagine that you had forgotten the road to our abode, from the length of time that has elapsed since you came this way. However, as I know that the reason of my silence is that I have not an hour at present that I can call my own, so I think in your case that not forgetfulness but press of business keeps you from coming to see us. It is some comfort, meanwhile, to have Vincenzio's visits, as we thus get news of you on which we can rely."

A daughter of Geri Bocchineri of Prato, Major-domo of the Grand Duke, was Maria Celeste's best friend in the convent, and is frequently mentioned in her letters as Sister Luisa. Shortly after Vincenzio's return home from Pisa he paid his addresses to a sister of this lady, Sestilia Bocchineri, and was accepted. This news greatly delighted Maria Celeste, and, on 4th January 1629, she writes to know when and how she should congratulate the bride, and as regards a wedding present: "As I have not the means to do as my mind prompts, I must take advantage of your kind offer of help."

Maria Celeste's satisfaction at the match was increased by her first interview with the bride.[1] She thought she perceived in her such signs of affection for her father as augured well for the comfort of his declining years. Writing on 22nd March, she says:—

"Both my sister and I were much pleased with her affable manner and good looks. But

[1] The marriage took place at Prato on 29th January 1629. Galileo was present at the ceremony.

what gave me the greatest joy was to see that she was fond of you, since from that we may judge that she will not be wanting in such loving attention as it would be our delight to render you were it permitted. . . .

"If you could manage to send back the clock on Saturday evening, the Sister, whose duty it is to call us to matins, will be greatly obliged."

From a later letter we learn that the clock, which had been sent first to one and then to another with no improvement, was going well now that Galileo had put it to rights. Some months later it got out of order again, and Vincenzio tried his hand at repairing it, but now (21st January 1630), it goes worse than ever. Yet, perhaps, its not going is more her fault than Vincenzio's, or, perhaps, it is because the cord is bad, or, perhaps—she doesn't know, but anyhow she sends it to her father, for mended the clock must be, and that quickly too, else these nuns will let her have no peace.

As evidence of Galileo's delightful faculty of turning his hand to everything, and of the odd jobs he was called on to do for the poor nuns of San Matteo, the following passage from Maria Celeste's letter of 10th September 1630 is interesting:—

"Now that the weather is getting cooler Sister Arcangela and I, with those of the nuns whom we love best, have planned to work together in my cell which is large; but the window is high, and wants 'glazing' in order that we may see a little better. I should like to send you the panels (or shutters) to glaze them with waxed linen, which even if old will

do very well. But I wish to know first what you think—not that I doubt your willingness, but because it is a piece of work fitter for a carpenter than for a philosopher."

The common window of that period was no more than an opening in the wall fitted with a shutter in which was a hole (or holes) to let in light when the shutter was closed in very hot and very cold weathers.

Towards the end of 1629, Galileo found himself face to face with yet another trouble which might have proved to be serious. He was menaced either with deprivation of his salary as Extraordinary Professor at Pisa, or with the loss of that leisure which had been the determining influence in his quitting Padua in 1610, and which he was now as anxious as ever to enjoy. Some ill-wishers at Pisa raised the question whether it was in the power of the Grand Duke to assign a salary out of the University funds to one who neither lectured nor resided there. This scruple had slept for nineteen years, so it is probable that those who now raised it reckoned on finding in young Ferdinando II. a less firm supporter of Galileo than his father Cosimo II. had been. But the matter did not proceed so far; the theologians and jurists, to whom the question was referred, decided that the Grand Duke had the power, but to put the matter beyond all further dispute, his Highness appointed Galileo to an equivalent post in the magistracy of the University, so that he was left undisturbed in the stipend and leisure which were now more than ever necessary in his old age and shattered health.

## CHAPTER XI

### COMPLETION AND CONTENTS OF THE DIALOGUE ON THE TWO PRINCIPAL SYSTEMS OF THE WORLD—THE PTOLEMAIC AND THE COPERNICAN

1630-1632

By the beginning of the year 1630, Galileo had completed his Dialogues, with the exception of an introduction or preface, an index, and a few finishing strokes here and there. In announcing this fact to his friends, he informed Prince Cesi that he intended going to Rome to see to the printing of the book—a step of which the Prince highly approved. The state of affairs at Rome just then seemed very favourable for this enterprise. Galileo's devoted disciple Castelli had been called from Pisa in 1624 to be mathematician to the Pope, and enjoyed great consideration with the Barberini family. This life-long friend also approved the design, and informed our philosopher (6th February) that Father Niccolò Riccardi, another old pupil and now chief censor of the press, had promised his assistance.[1]

Another letter of 16th March contained equally encouraging news. According to this, the celebrated Dominican monk, Tommaso Campanella, had just told the Pope that, a short time before, he had tried

[1] He was officially known as Master of the Sacred Palace.

to convert some German nobles to the Catholic faith; that they were favourably disposed until they heard of the prohibition of the Copernican theory, when they indignantly declined to have anything more to say to him. To this Urban replied: "It never was our intention, and if it had depended upon us that decree would not have been passed." In other letters Ciampoli and Castelli urged their old master to set out at once for the Papal residence, "where they were longing for him more than for a lady-love." In the face of these fresh indications of an altered, or, at least, tolerant attitude towards science, we cannot be surprised at Galileo concluding that under Urban VIII. an infringement of the decree of 1616, in the spirit if not in the letter, such as his Dialogues undoubtedly were, would give no offence at the Vatican.

While his friends were thus urging him to set out, his daughter, knowing how frail he was, contemplated the journey with anxiety. In her letter of 14th March, she hopes he will come to see them before he goes. Then, after saying how busy she is, and reminding him of his promise to send her what we now call "A Polite Letter-Writer," comes the housewifely P.S.—"If you want any collars washed please send them; and eat these fresh eggs for love of me." Maria Celeste is clearly the "scholared" one of the convent. She writes letters for the poor nuns; helps the Mother Abbess in her official correspondence, and concocts petitions and begging letters to "people of quality, such as Governors, Workmen,[1] and such-like personages."

[1] *Operai*, may also mean administrators.

For many days she goes on hoping to see her father, but he is absorbed in the final revision of his book, and has no time to go to San Matteo —even to wish his daughters the customary Easter greetings. Maria Celeste could not refrain from an affectionate remonstrance; she knows he is immersed in study, but she does not wish him to shorten his precious life for the sake of fame. He must take care of his health for his own sake, and for his children's sake.

On 12th April, he found time to pay the long-wished-for visit, and he was made to promise another, which was to be a kind of family gathering in the convent parlour, where the two sisters would entertain their father, brother, and sister-in-law at a dinner (to be provided by Galileo). Wishing, dear soul, that the banquet should be worthy of the occasion, and fearing that her father in his scientific abstraction would send unsuitable things, she reminds him that she does not want either lemons or rosemary, but something more substantial, in particular a flask of his good wine, two cream cheeses, and some dish that will do to come after the roast.

The Mother Abbess could not let pass such an opportunity of detailing the needs of the convent, and enlisting Galileo's good offices towards procuring some relief from Rome; and she had as little hesitation in preferring the request as doubt of its being granted. Why not? Maria Celeste was loved by her father who could refuse her nothing, Galileo himself was the Pope's friend, and surely he could obtain alms for her at Rome,

as easily as mend the convent clock; lend her money when hard pressed; and give them wine and fruits and other eatables from his cellar and garden.

Filled with hope and with his MS. complete, Galileo at length set out on 1st May in a Court litter, and travelling fast arrived in Rome on the evening of the 3rd. Furnished with a letter of introduction from the Grand Duke's chief secretary, Andrea Cioli, to the Tuscan ambassador, Francesco Niccolini, he was most hospitably received by that gentleman and lodged in the Embassy, where he quickly gained the friendship of the ambassador and his wife, which as we shall soon see was to be so useful to him.

Soon after his arrival he had a long audience of the Pope, and wrote on 18th May to Florence in high spirits: "His Holiness has begun to treat my affairs in a way that permits me to hope for a favourable result." Nevertheless, the result was anything but favourable; indeed, the toleration, to say nothing of the recognition, of the Copernican theory so ardently hoped for was as far off as ever. Urban VIII. would not object to the publication, but certain conditions would have to be fulfilled. The title of the book, "Dialogues on the Flux and Reflux of the Tides," was misleading and would have to be altered. The subject being really a discussion of the relative merits of the Copernican and Ptolemaic systems, this would have to be indicated in the title. The subject, moreover, would have to be treated from a purely hypothetical standpoint, and this fact must be

clearly set forth in a preface or introduction. Then, the book must conclude with an argument which the Pope communicated to Galileo in 1624,[1] and which his Holiness considered unanswerable. As great importance will attach itself to this argument in the sequel, we beg our readers to note it carefully. It is as follows: God is all-powerful; all things are therefore possible to Him; *ergo* the tides cannot be adduced as a necessary proof of the double motion of the earth without limiting God's omnipotence—which is absurd.

Rather than forego the publication of a work towards which he had laboured and thought for over thirty years, Galileo consented to these conditions. Doubtless, he felt that such minds as were capable of following his reasoning in favour of Copernicanism would no more be prejudiced by the hypothetical warning in the introduction than by the unanswerable argument of the conclusion.

Meanwhile, the MS. was submitted to Father Riccardi, the Papal censor, and by him passed on to his assistant Father Raffaele Visconti, who carefully went through it, altered many passages, and finally approved the work thus revised. By this time the middle of June had arrived, and Galileo was anxious to leave Rome before the great heat set in. Riccardi read over the MS. once more and then granted his permission for the printing of the work in Rome. Thus, by the end of June 1630, Galileo was back in Florence

[1] When Galileo's theory of the tides was being discussed in Rome. Doubtless, his Holiness brought forward his argument again at the recent interview.

with his MS. duly revised and corrected, and with the ecclesiastical *Imprimatur* for its publication in Rome, on the understanding that a preface and conclusion were added in accordance with the Papal wishes. But events were now at hand which long delayed Galileo's ardent desire to see his work speedily given to the world, and which involved complications afterwards taken advantage of by his watchful enemies.

Soon after his return from Rome, Galileo wrote to his daughter, and from her reply of 21st June, we learn that he was ill again :—

"Just as I was thinking of sending you a long lamentation because of your never coming near us, I received your most loving letter which shut my mouth completely. We were truly grieved to hear of your being ill; but really, after making a journey at this time of the year, and with the plague everywhere, I do not see how it could be otherwise. I am astonished to hear of your going into Florence every day. Pray take a few days' rest; do not even come to see us. We would prefer you kept well to the pleasure of your company."

The plague, already rife within the city walls, now began to spread to the suburbs. Even the fashionable Bellosguardo, whose reputation for salubrity equalled the beauty of its situation, was not spared. One of Galileo's own household, a glass-blower, was taken off early in October; and soon after, his son Vincenzio, seized by a panic, fled with his wife to Prato, leaving his invalid father alone, and his seven-months'-old

baby out at nurse in the neighbourhood of the villa!

On 18th October, Maria Celeste wrote:—

"I am troubled beyond measure at the thought of your distress, and am horrified at the sudden death of your poor glass-blower. I entreat you to omit no possible precaution against the present danger. I believe that you have by you all the remedies and preventives that are required, so I will not repeat. Yet I would entreat you, with all reverence and confidence, to procure one more remedy—the best of all, to wit, the grace of God, by means of true contrition and penitence. This is without doubt the most efficacious remedy both for soul and body. For, if in order to avoid this sickness it is necessary to be always of good cheer, what greater joy can we have in this world than the possession of a good and serene conscience? . . . I pray your Lordship to accept these few words prompted by the deepest affection.

"I wish also to acquaint you with the frame of mind in which I find myself at present. I am desirous of passing away to the next life, for every day I see more clearly the vanity and misery of this present one. There I would hope that my prayers for your Lordship would have greater efficacy."

Ten days later, 28th October, she asks if her brother has really fled to Prato.

"I was thinking," she continues, "I would write to give him a piece of my mind, and advise him not to go, or, at any rate, not to leave the household so inconveniently situated. His going away in this manner really is exceedingly strange

at this present juncture, as there is no saying what may happen. However, fearing to make matters worse, I did not put my intention into effect. I have the assurance that Almighty God will supply you by His providence where men fail you."

From her next letters we infer that Vincenzio as still away, leaving his aged father with a scanty household. His idleness all along had been a cause of great pain to Galileo. With no energy to help himself, and too conceited to accept any appointment not commensurate with his ideas of his own importance, he preferred to live an ignoble life at his father's expense. On 2nd November, Maria Celeste tries to console her father in a long, prattling, and most touching letter. She entreats him sweetly not to brood over his loneliness, not to be too angry at Vincenzio's cowardly and ungrateful conduct, but to fix his thoughts on heaven :—

"I pray you," she continues, "not to take the knife of these crosses and tribulations by the wrong end, but rather take it by the haft and use it to cut through all the imperfections which you may discover in yourself, that being thus freed from all impediments you may, as with a lynx-like eye by which you have penetrated the heavens, penetrate in like manner the things of this lower world, and so come to know the vanity and fallacy of all earthly things. . . . I pray your Lordship pardon me if my chattering becomes wearisome. You incite me to it by telling me you are pleased to have my letters. I look upon you as my patron saint (to speak according to our custom here) to

whom I tell all my joys and griefs, and finding you always ready to listen I ask, not indeed for everything I want, for that would be too much, but just for what I find most needful. Now the cold weather is coming and I shall be quite benumbed if you do not send me a counterpane, for the one I am using at present is not mine, and the person to whom it belongs wants it back. The one you gave me, as well as the woollen one, I have given to Sister Arcangela. She prefers sleeping alone, and I am quite willing she should do so. But in consequence I have only a serge coverlet for myself. So I entreat my most beloved *Devoto*, who I know well cannot bear that I should want for anything. . . . I send you two pots of electuary as a preservative against the plague. The one without a label consists of dried figs, walnuts, rue, and salt, mixed with honey. A piece of the size of a walnut is to be taken in the morning fasting, with a little good wine. They say its efficacy is truly wonderful. The contents of the other pot are to be taken in the same way.

"You said in your letter that you had sent me the telescope, but you have forgotten to do so, therefore I remind you of it;[1] also of the basket in which I sent you the quinces, as I want to send some more if I can meet with any."

Galileo appears to have promised his daughters a visit in the beginning of December, but the *tramontana* (the cold wind from the Apennines) was blowing hard, and the old man dared not face it. In consequence, Maria Celeste sends one of her little notes (15th December) and some of the never-

[1] She uses the word *occhiale*, but Professor Favaro thinks she meant *occhialino* or microscope, which no doubt Galileo intended for her amusement.

failing preserved citron. She also asks for the wherewithal to make a few Christmas presents; some stuff to make a door-curtain; and a few trifles, such as reels, sulphur matches, wicks, and tags. If not in the house he was not to send out for them, she would prefer to go without them, to running the risk of the messenger bringing back the plague from the city.

In a letter of 18th February 1631, Maria Celeste says:—"I am quite confused at hearing that you keep all my letters. I fear that your great love for me makes you think them more perfect than they are." This little fact shows very clearly the esteem in which he held her. He had, no doubt, been pouring out his tortured soul to her. Stung by his son's misconduct, by his brother's selfish waywardness, and by the little consideration of other relatives, it must have been a comfort to him to turn to the only one of his family whose life was a mingled hymn of gratitude for his kindness and of prayers for his welfare. It must have helped to soothe his aching heart to know that there was one being in the world who would not misunderstand his motives and actions, and whose sympathies were his in joy and in sadness.

Early in the summer of 1631, feeling age and infirmity creeping surely over him, he began to think of a change of residence from Bellosguardo to the neighbourhood of the convent, where he would be able to enjoy more often his daughter's society. Maria Celeste's letters show how eager she was to hear of a house which would combine vicinity to the convent with a good situation, and a rent suitable to

her father's much-drained purse. House-hunting in the neighbourhood of Florence was not then the easy work it is nowadays, such villas as existed being mostly occupied by their owners. Vincenzio, who appears to have got over his sulks and fear of the plague, was back again with his father, and helped in search for a house. Maria Celeste heard of two or three, but there was something against them all, and it was not until August that she heard of one which she considered suitable in every way. Writing on the 12th, she says:—

"I am so anxious to have you in the neighbourhood that I am constantly enquiring if there is any place near here to let. I have just heard of a villa belonging to Signor Esau Martellini which is situated on the Piano de Giullari, and bounds our garden. I write at once to tell you that you may see if it be to your liking. I should be glad indeed if it were, as then I should not be obliged to remain so long without news of you as is the case at present."

Shortly afterwards, Dame Piera (Galileo's old housekeeper) going to the convent with a basket of provisions, rejoiced the daughter's heart by telling her that there was every prospect of the villa Martellini being taken. As Maria Celeste's last letter addressed to Bellosguardo is dated 30th August, it would seem that very soon after, Galileo took up his abode in the village of Arcetri in Martellini's villa, then called "Il Giojello" (the jewel), and now known as Villa Galileo. There, not five minutes' walk from the convent (indeed the grounds of the two houses adjoined) he was able to have daily intercourse with his daughters, and Maria Celeste no

longer found difficulty in procuring a messenger if necessary to send affectionate enquiries about his health, or little presents from the still-room and pharmacy.

> "Nearer we hail
> Thy sunny slope, Arcetri, sung of old
> For its green wine; dearer to me—to most,
> As dwelt on by that great astronomer,
> Seven years a prisoner at the city-gate,
> Let in but in his grave clothes. Sacred be
> His villa (justly was it called the Gem!)
> Sacred the lawn, where many a cypress threw
> Its length of shadow, while he watched the stars!
> Sacred the vineyard, where, while yet his sight
> Glimmered, at blush of morn he dressed his vines,
> Chanting aloud in gaiety of heart
> Some verse of Ariosto!"
>
> —ROGERS' *Italy.*

Arcetri is full of memories of the great Florentine philosopher. On the road front of his villa is a white marble slab with a long inscription placed there in November 1788, by Gio. Battista Nelli,[1] and commemorating the fact that Galileo lived there from the Kalends of November 1631 to the Ides of January 1642. Over the inscription is a bust with the words: "This effigy of the divine Galileo was erected in 1843 by Anton: Filippo Marchioni."[2]

On the way back to town, soon after leaving Arcetri, one comes to the picturesque old Torre del Gallo, from the tower of which one gets a glorious

[1] One of his biographers—"Vita e Commercio Letterario di Galileo Galilei," Lausanne, 1793. For inscription, see Albèri's edition, vol. xv. p. 395.

[2] On the front of a house opposite to the entrance to the villa is an old sun-dial said to be the work of Galileo.

view of the surrounding country, extending from the wooded heights of Vallombrosa on the east, to the distant Carrara mountains on the west; and from Certosa and away along the Roman road to the south, to the heights of old Fiesole on the north, with the Val d'Arno and Florence in between.

> "Of all the fairest cities of the earth
> None is so fair as Florence."
> —ROGERS' *Italy.*

A chamber in the tower is arranged as a Galilean Museum, and is full of relics of the philosopher and his contemporaries, as portraits, busts, engravings, autographs, and medals; instruments of various kinds, as telescopes, thermometers, hour-glass, etc. Amongst the paintings we would particularly direct the visitor's attention to those of Galileo before the Inquisition; Galileo, blind and in bed, dictating to his son and his last disciples Viviani and Torricelli; and portraits of the two latter.[1]

It is popularly supposed that Galileo used the Torre del Gallo as an observatory. There seems, however, to be no ground for this belief; but that he sometimes came here to enjoy the grand panorama displayed from the top is likely enough.

Not far from the Torre del Gallo, and still on the way to Florence, one comes to the Piazza degli Uganelli. Here the great painter Sustermans

[1] Quite recently the Torre del Gallo has changed hands, and the Galilean relics, etc., have been dispersed.

The Torre del Gallo, Arcetri, Florence.

[To face p. 238.

lived, and here in 1635 he painted his celebrated portrait of Galileo. A photographic copy of this is reproduced as the frontispiece to this volume. This picture, which is thought by experts to be Sustermans' *chef d'œuvre*, has a history. It was sent by Galileo as a present to his friend and correspondent, Elia Diodati of Paris. Twenty years later, and as a special favour, it was returned to the Grand Duke; and later still it was placed in the Uffizi Collection by Cardinal Leopoldo de Medici—"In order to show to all two marvels of nature, in the *person* of him who is represented, and in the *art* of the painter."[1]

All this time, from soon after his return from Rome, Galileo was tormented with the obstacles and delays which he encountered in the printing of his Dialogues. It would detain us too long and be little profitable to set out these complications in detail; but they are so well summarised by Galileo himself in a letter of 7th March 1631, to Chief Secretary Cioli, that we venture to reproduce it as follows:—

"As your Lordship knows, I went to Rome for the purpose of getting permission to publish my Dialogues, and to this end I put them in the hands of the Master of the Sacred Palace, who committed them to the care of his colleague, Father Raffaele

[1] Sustermans was born in Antwerp 1597, settled in Florence and there died in 1681. There is another portrait of Galileo in the Pitti Palace Collection (No. 106, Hall of Mars), which has been attributed to Sustermans, but is now supposed to be the work of one of his pupils. See on this disputed point Favaro's "Documenti Inediti per la Storia dei Manoscritti Galileiani," Rome, 1886, pp. 102-3 and 109.

Visconti, that he may examine them with the greatest attention, and note any doubtful matter or any conceit of imagination requiring correction, which (at my own request also) he did most thoroughly. And when I entreated the Rev. Master to grant me the required licence, his Reverence signified his wish to read the whole MS. through once more. This was done, after which he returned the book with the licence signed with his own hand; whereupon I, having been in Rome for two months, returned to Florence, intending to send back the book (as soon as I had added the dedication or preface, the conclusion, and a few other necessary things) to the illustrious Prince Cesi, President of the Lyncean Academy, who had always superintended the printing of my works. But owing to the death of this Prince [on 2nd August 1630] and the interruption of communications [by the plague], I was hindered from printing the work in Rome, and decided on having it done here. I had arranged matters with an able printer and publisher, and had procured the licence of the Rev. Vicar, and of the Inquisitor, and also of the illustrious Signor Niccolò Antella. I informed the Rev. Master of the Palace of all that had taken place, and of the impediments in the way of the printing in Rome. Whereupon he informed me, through our Ambassador, that he wished to have another look at the book, and that I was to send him a copy. On this I came to you, as you know, to ask if it were possible to send such a large volume to Rome with security, and you replied certainly not, and that letters were hardly safe. On this I wrote again, stating the impediments, and offering to send the preface and the end of the book, to which the superior authorities might add if they saw fit, or take away, or add notes of explanation; for I myself do not refuse to call these

thoughts of mine chimeras, dreams, paralogisms, and vain imaginations, submitting the whole to the absolute wisdom of my superiors. As to the further revision of the body of the work, I suggested it might be done here by some person named by the Rev. Father. He was content that it should be so, and accordingly I sent him the preface and the end, and he authorised Father Jacinto Stefani, Counsellor of the Inquisition in Florence, to revise the work. This he did with the greatest care, observing even the minutest points which neither to him nor to my most malignant adversary could give the slightest umbrage.[1] Indeed, the Rev. Father declared that the reading of my book had drawn tears from him more than once, when he saw with what humility and reverent submission I deferred to the authority of my superiors. And he declares, as do all who have read the book, that I ought to be entreated to publish it, instead of being hindered in so many ways, of which I need not here adduce examples.

"Weeks and months ago I heard from Father Castelli that he had often met the Rev. Master who had given him to understand that he was going to send back the preface and the end, arranged to his entire satisfaction; but this has not yet been done.[2] The papers have been thrown aside into some corner, and my life is wasting away, and I am in continual trouble. I went into town

[1] "The reviser here, finding nothing to alter, but in order to show that he had gone carefully through the MS., contented himself with substituting some words for others, as for instance, in several places, 'universe' for 'nature,' 'quality' for 'attribute,' 'sublime spirit' for 'divine spirit'—excusing himself to me by saying he foresaw that I should have to do with fierce foes and bitter persecutors, as indeed has come to pass."—Galileo to Elia Diodati, 15th January 1633.

[2] Evidently some intrigue was afoot in Rome to stifle the book. Castelli wrote 24th August 1630, recommending for many most weighty reasons, which he did not wish just then to put on paper, that the work be printed in Florence, and as quickly as possible.

yesterday at my Serene Master's command, to see the designs for the façade of the Cathedral, and also wishing to avail myself of his kindness, so that, taking counsel with your Excellency, some means may be found for making the Rev. Master explain himself—as that the Ambassador be instructed to signify his Highness's desire for a termination of this weary business, and to let him know what sort of man his Highness has for a servant. But so exceedingly troubled was I that I could neither speak to his Highness nor look at the designs. Just now a messenger from Court has come to know how I am, and truly I am in such a state that I should not have risen from my bed had I not wished so particularly to tell your Lordship of this business, and to beg you to do for me that which I was unable to do yesterday, and to take the matter into your own hands, so that I may, while life yet remains, see what result I may expect from all my long and heavy labours. I send this by the hand of the Court messenger, and shall await your reply through Signor Geri Bocchineri. And since his Highness is so anxious to learn the state of my health I beg you to tell him that I should be pretty well in body, were I not so afflicted in mind."[1]

The ambassador, Niccolini, was instructed to act in accordance with Galileo's wishes, and after

[1] In this letter Galileo refers incidentally to one of the few occasions on which his advice was sought in the public service, so far as we know from documentary evidence. Another occasion occurred a short time previously, namely, a disastrous inundation of the river Bisenzio. His report, in which he recommended the canalisation of the river, is dated 16th January 1631, and addressed to Raffaello Staccoli, the Auditor-General of Tuscany. On the 22nd July of the same year, he addressed another report to the Grand Duke on the proposed canalisation of the Arno. For some interesting information on these subjects, see Napier's "Florentine History," London, 1847, vol. vi. pp. 393-448.

more months of vexatious objections and delays, and not until, as Niccolini says, "formally pulled by the hair," Riccardi sent back the preface and end, now quite in order, to the censor in Florence. In his covering letter of 19th July 1631, he says:—

"Conformably to the orders of our Lord (the Pope) respecting Signor Galileo's book, besides what I wrote to your Reverence concerning the body of the work, I send you the preface, with liberty to the author to alter or embellish as to the wording, so as the substance is preserved. The end may be treated in the same way."

By early autumn, and after a second revision of the whole work by Father Stefani in accordance with precise instructions from Rome, all the conditions of the censorship were finally complied with, and permission to print the book in Florence was issued in due form of *Imprimatur*. In all these annoying hindrances Galileo had a foretaste of the persecution which was to be his lot for the rest of his life.

We shall devote the rest of this chapter to giving an idea of the plan and style of the work, and a *résumé* of its contents. The book, which is dedicated to Ferdinando II., bears the following title, unusually long in an age of long titles:—"Dialogue of Galileo Galilei, Lyncean, Mathematician Extraordinary of the University of Pisa, Philosopher and First Mathematician of the Most Serene Grand Duke of Tuscany; where in meetings of four days are discussed the Two Principal Systems of the World, in-

determinately proposing the Philosophical and Natural arguments, as well on one side as on the other." It is written in Italian, and in a style adapted not for the learned alone, but intelligible and attractive to every one of ordinary education. His reason for writing in Italian instead of in Latin — the usual vehicle fo philosophical subjects—is characteristic.

"I write in Italian," he says, "because I wish every one to be able to read what I say. I see young men brought together indiscriminately to study to become physicians, philosophers, etc., who although furnished, as Ruzzante might say,[1] with a decent set of brains, yet being unable to understand things written in gibberish, assume that in these crabbed folios there must be some grand hocus pocus of logic and philosophy much too high up for them to jump at. I want such people to know that as Nature has given eyes to them just as well as to philosophers for the purpose of seeing her works, so she has given them brains for examining and understanding them."

The dialogue is carried on by three interlocutors, two of whom adduce the scientific reasons for the double motion of the earth, while the third honestly tries to defend the opinions of the Ptolemaic and Aristotelian schools. Galileo gave to the defenders of the Copernican doctrine the names of two of his warmest friends, both long dead—Filippo Salviati of Florence (died 1614), and Gio Francesco

[1] Ruzzante, whose real name was Angelo Beolco, was a Paduan (1502-1542), and the writer of racy stories and ridiculous incidents in the Paduan dialect.

Sagredo of Venice (died 1620). Salviati is the special advocate of the Copernican doctrines; Sagredo is witty, impartial, and open to conviction, a half convert, but an acute and ingenious one. To him are allotted the objections which seem to have some real force, as well as lively illustrations and digressions which would be inconsistent with the gravity of Salviati's character. Simplicio, a name borrowed from the noted Sicilian commentator of Aristotle who wrote in the sixth century,[1] is of course a confirmed Ptolemaist and Aristotelian, and produces successively all the scientific arguments of the peripatetic school; and as these fail to convince, he has recourse to all the arts of sophistry. Placed between the wit and the philosopher, it may be guessed that his case fares badly, in fact, he is chaffed and confuted at every turn, so that no unbiassed reader can fail to perceive the superiority of the modern theory; and as Galileo puts into the mouth of Simplicio not only every possible argument in favour of his case, but also every possible objection to the other side, this superiority is made to appear all the more striking.[2]

The condition that the Copernican doctrine is only to be treated as an hypothesis is ostensibly

[1] Miss Clerke (*verbo* Galileo, "Encyc. Brit.") says that this choice of name was "doubtless instigated by a sarcastic regard to the double meaning of the word"; but there seem to be no grounds for the suggestion. Indeed, Galileo says distinctly in his preface that the name was suggested by that of Aristotle's commentator. The name is used again in his "Dialogues on the New Sciences," published in 1638.

[2] A favourite method, see p. 161 *ante*.

complied with. If Salviati or Sagredo show the untenableness of some Ptolemaic axiom, or add a stone to the Copernican structure, a remark is interpolated by one or other to weaken the effect. When, for instance, it is said that the final decision in the controversy rests neither with mathematics and physics, nor with logic and philosophy, but with "a higher insight"; or when Salviati repeatedly asserts that he does not wish to maintain the Copernican doctrines as *true*, and uses the qualifying word "possible," or speaks of them as "fantasies" and "most vain chimeras," the reader cannot fail to see that these reservations, which always occur at critical moments, are made with the purpose of appeasing the censors.

When we remember its history we cannot be surprised that the preface or introduction has no logical agreement with the contents of the Dialogue. It is addressed "To the Discreet Reader," and runs as follows:—

"Some years ago a salutary edict was promulgated at Rome, which, in order to obviate the perilous scandals of the present age, enjoined an opportune silence on the Pythăgorean opinion of the earth's motion. Some were not wanting who rashly asserted that this decree originated, not in a judicious examination, but in ill-informed passion; and complaints were heard that counsellors totally inexperienced in astronomical observations ought not by hasty prohibitions to clip the wings of speculative minds. My zeal could not keep silence when I heard these rash lamentations, and I thought it proper, as being

fully informed with regard to that most prudent edict, to appear publicly as a witness of the actual truth. I happened at that time to be in Rome; I was admitted to the audiences, and enjoyed the approbation of the most eminent prelates of that Court; nor did the publication of the aforesaid decree occur without my receiving some prior intimation of it. Wherefore it is my intention in this present work to show to foreign nations that as much of this matter is known in Italy (and particularly in Rome) as ultramontane diligence can ever have formed any notion of, and (collecting together all my own speculations on the Copernican system) to show them that the knowledge of all these preceded the Roman censures, and that from this country proceed not only dogmas for the salvation of the soul, but also ingenious discoveries for the gratification of the understanding. With this object I have taken up in the dialogue the Copernican side of the question, treating it as a pure mathematical hypothesis, and endeavouring in every artificial manner to represent it as having the advantage, not over the opinion of the stability of the earth absolutely, but over it as taught and defended by some who profess to be peripatetics, but retain only the name, and are content, without improvement, to worship shadows, not philosophising with their own reason, but only from the recollection of four principles imperfectly understood."[1]

The conclusion agrees no better than the preface with the body of the work. At the end of the fourth day, which is almost wholly taken up with the question of the tides, comes naturally

[1] It will be noted that this preface is in much the same style as the introduction to his Ingoli letter. See p. 212 *ante*.

the Pope's "unanswerable" argument of 1624 (p. 230 *ante*). Salviati treats it accordingly:—

"It is," he says, "an admirable and truly angelic argument, and perfectly in accord with that which, coming from God Himself, permits us to discuss the constitution of the world—doubtless with the view of preventing (by exercising them) the diminution and enfeeblement of our intellectual faculties, while withholding from us the power of fully comprehending the works of His hands. May this exercise (permitted and ordained by God) enable us to see and admire His greatness, which is all the more necessary since we shall never be able to penetrate the depths of His infinite wisdom."

Sagredo then says:—

"Let this reflection be a fitting conclusion to our four days' discussion. And now, if Salviati desires some repose, our curiosity will concede the delay, but only on condition that at his earliest convenience he will satisfy us as to the problems reserved for future meetings. For myself, I am extremely anxious to hear his exposition of the elements of the new science of local motions, natural and violent, as elaborated by him."

As regards the contents of the Dialogues, we can only give an outline. Salviati opens the conference by defining its object, which is to examine all the physical arguments evoked for and against their opinions by the defenders of Aristotle and Ptolemy on the one hand, and of the Copernican doctrine on the other.

No discussion could be undertaken without first enquiring into Aristotelian doctrines, which formed the basis of current theory. In a few words those

amounted to a statement, that whereas things earthly are imperfect and full of change, things heavenly are eternal, unchangeable, and perfect. Salviati proves that this statement, in the spirit in which it was usual to accept it, was in reality untenable. The telescope showed him imperfections on the sun's surface, which was contrary to the belief that that body was unchangeable and free from blemish. He lays no great stress on the instance of comets (whose real nature Galileo never understood), but quotes the recent new stars (of 1572 and 1604) as instances of further change in the heavens. He thus prepares the way for a still wider departure from Aristotelian theory; he insists that the time has come to consider the nature of the world *de novo*, respectfully suggesting that Aristotle, had he the opportunities which the invention of the telescope afforded, would himself have been the first to realise the inadequacy of his dogmas on this subject.

Salviati proceeds to point out certain resemblances between the earth and moon and the more distant heavenly bodies. It is shown that the moon only shines in virtue of the sunshine falling on her. The idea that the earth might similarly appear luminous to any inhabitant—could one be imagined to exist—on the moon is less familiar, and less readily accepted. And yet the visibility of the moon during a total eclipse of the sun, and the appearance "of the old moon in the arms of the new" (as we now speak of it), are more probably due to reflected earth-light than to any other cause. This is discussed at some

length, and the phenomena of Venus's phases (revealed by the telescope) are shown to be similar to those of the moon, and may be explained as due to the same cause. Venus then, like the moon, owes her brilliance to sunlight falling on her. The same probably applies to Mercury and Mars. The obvious inference seems to be that all of these heavenly bodies are not so unlike the earth as men had always been taught to believe. Points of resemblance there certainly are, and there may be many more, which the distance of the planets alone prevents us from discovering. Salviati refers to the common spherical form of earth, sun, moon, and planets, suggesting the existence of a common cause for that shape. The passage is striking enough to quote:—

"Just as from the mutual and universal tendency of the parts of the earth to form a whole, it follows that they all meet together with equal inclination, and, that they may unite as closely as possible, they assume the spherical form, and so we ought to believe that the moon, the sun, and other mundane bodies are also of a round figure, if for no other reason than from a common instinct and natural concourse of their component parts; whence, if by accident any one should be violently separated from its whole, it is reasonable to believe that spontaneously and of its natural instinct it would return."[1]

[1] Here follow some remarks which show that the idea of universal gravitation hovered round Galileo's mind without fully entering it. He perceived the analogy between the power which holds the moon in the neighbourhood of the earth, and compels Jupiter's satellites to circulate round their primary, and that attractive power which the earth exercises on bodies at its surface; but he failed to conceive the

Having laid stress on the resemblance of earth and planets as a probable theory, Salviati proposes for them all a similar motion round the sun—one of the two main points of the new Copernican doctrines. He shows how by this hypothesis the apparent paths of the planets can all be explained. And the simplicity of his explanation as contrasted with the Ptolemaic system appeals to common-sense, in a way which in itself almost carries conviction. A glance through a telescope turned towards Jupiter shows a family of small bodies circling round a great planet; here one could see on a small scale the very thing that Copernicus had described as going on in the case of planets and sun on a much larger scale, the sun being in the latter case the central body which corresponded with Jupiter in the other.

On the second "Day" the discussion passes on to the other chief point in the Copernican hypothesis, that the daily motion of the stars is only apparent, being due to a real daily rotation of the earth on its polar axis. Various objections are brought against this. The opponents of the earth's diurnal motion maintained that, if that motion were real, a stone dropped from the top of a tower would not fall at its foot. In the same way it was stated that a stone dropped from the masthead of a ship would fall near the stern, in consequence of the ship's velocity. But, strange as it seemed to Simplicio, it is nevertheless true

combination of central force with initial velocity, and was disposed to connect the revolutions of the planets with the axial rotation of the sun—a notion which tended more towards Descartes' theory of vortices than towards Newton's theory of gravitation.

that the stone falls at the foot of the mast, the ship's motion, provided it be uniform, having no power to disturb its fall. In a variety of forms the argument is brought forward, that if the earth be really rotating we on its surface ought to be sensible of the fact, either by our direct power of feeling, or else by irregularities in the motion of the things about us. There is a single reply to all such contentions, viz., all bodies on or near the earth's surface share the earth's motion, even the lower parts of the atmosphere being carried on by it, and, therefore, as all such things have a common motion, their relations to one another are just as if the motion did not exist. "Motion is so far motion (and as motion it operateth) by how far it hath relation to things which want motion; but in those things which all equally partake thereof it hath nothing to do, and is as if it never were." Salviati justifies this contention by a forcible illustration. A ship is out for many months on an ocean voyage, touching at various ports, and sailing now east, now west. Fix the attention on a single bale of cargo, packed tight in the hold; and, though the ship may have been tossed about in all directions by winds and waves, we are justified in saying that that particular bale of cargo has not moved during the long journey from port to port. Let the mate go down into the hold and disturb that bale from its place by one inch, and it has had in relation to the rest of the cargo a greater motion than it acquired during all the time that ship and cargo were voyaging together; the disturbances that were

common to all had no visible effect inside the hold.

No objections to the hypothesis of the earth's rotation being found tenable, it is shown by Salviati how much more simple is the real motion proposed than the supposition that the universe revolves daily round a fixed earth. "To make the universe revolve," he says, "in order to maintain the immobility of the earth is as little reasonable as to require, in order to see Venice from the top of the Campanile, that the whole panorama should move round the spectator instead of his simply moving his head."

The primitive notion of the stars as fixed in a crystal sphere had been long overthrown. And, supposing accordingly that the stars were distinct and independent bodies, it was difficult to imagine laws controlling their motion about a fixed earth that should result in revolutions timed uniformly for all and at the same time of enormous rapidity. Salviati makes the improbable to be practically impossible by referring to the phenomenon now known as the "precession of the equinoxes," in virtue of which the direction of the earth's axis in space moves slowly, completing a revolution in about 26,000 years. The system of stellar motions that would be necessary to account for this would be inconceivably complex.

A great part of the third "Day" is devoted to the question of stellar parallax. In this lay one of the most serious difficulties of the Copernican theory. If it was true that the earth swept round the sun in a circular orbit some two hundred

millions of miles in diameter, then it must follow that at one time of the year we should get an entirely different view of the arrangement of the stars from that obtained six months earlier or later when the earth was at the opposite point of its orbit. The nearer stars should in fact undergo displacements in their apparent positions relative to those more distant. The answer to this was that these displacements probably did take place, but were too minute to be detected. But this answer, though strictly true, implied that the distances of even the nearest stars were great beyond all comprehension; and this in turn implied that the visible size of the stars indicated a real size of inconceivable dimensions. The latter difficulty was reduced by Salviati's assertion that the visible size of a star was an optical illusion; the telescope showed the stars to be sharp points, in contrast to the planets which, though small to the eye, really did possess visible dimensions. But the former difficulty remained, and nearly two centuries passed before Bessel made the first rough measurement of a stellar parallax. His method was essentially that suggested in the dialogue by Salviati; though the results obtained indicated for the star 61 *Cygni*, a distance which would probably have astonished even Galileo himself.[1]

With the difficulties of stellar parallax still uppermost in his mind, Simplicio looks at the utilitarian side of the question, and remarks :—

"All this is very well, and it is not to be

[1] More recent measurements fix the distance of this star at about 400,000 times that of the sun.

denied that the heavens may surpass in extent the capacity of our imaginations, nor that God might have created them a thousand times larger than they are. But we ought not to admit anything to be created in vain, or useless in the universe. Now we see this beautiful arrangement of the planets disposed round the earth at distances proportioned to the effects they are to produce upon us for our benefit. To what purpose, then, should such a vast vacancy be afterwards interposed between the orbit of Saturn and the starry spheres, containing not a single star, and altogether useless and unprofitable? to what end? and for whose use and advantage?"

SALVIATI: "Methinks we arrogate too much to ourselves, Simplicio, when we assume that the care of us alone is the adequate and sufficient work and limit beyond which the Divine wisdom and power do nothing and dispose of nothing. I feel confident that nothing is omitted by God's providence which concerns the government of human affairs; but that there may not be other things in the universe dependent on His supreme power, I cannot, with what power of reasoning I possess, bring myself to believe. So that when I am told of the uselessness of an immense space interposed between the orbits of the planets and the fixed stars, I reply that there is temerity in attempting by feeble reason to judge the works of God, and in calling vain and superfluous every part of the universe which is no use to us."[1]

SAGREDO: "Say rather that we have no means of knowing what *is* of use to us. I hold it to be one of the greatest pieces of arrogance and folly that can be in this world to say, because I know

[1] It is in the course of this discussion that Galileo says, "The space comprised between Saturn and the fixed stars is, perhaps, occupied by invisible planets." The discovery of Uranus and Neptune has confirmed this conjecture.

not what use Jupiter and Saturn are to me, that therefore these planets are superfluous. Nay more, that there are no such bodies in existence. To understand what effect is worked upon us by this or that heavenly body (since you will have it that all their uses must have a reference to us) it would be necessary to remove it for a while, and then the effect which I find no longer produced on me, I may say depended on that body. Besides, who will dare to say that the space (called too vast and useless) between Saturn and the fixed stars is void of other bodies belonging to the universe? Must it be so because we do not see them? Then, the four Medicean planets and the companions of Saturn came into the heavens when we began to see them, and not before! And by the same rule the innumerable host of fixed stars did not exist before men saw them. The nebulæ, which the telescope shows us to be constellations of bright and beautiful stars, were, till the telescope was discovered, only white flakes! Oh, presumptuous! rather, oh rash ignorance of man."[1]

Towards the end of the third "Day," reference is made to an *annual* rotation of the earth about an axis perpendicular to the plane of its motion. In ancient and mediæval times a simple state of revolution of the earth round the sun would have implied a revolution in which the same side of the earth was always turned to the sun; the

[1] Compare this with the "arguments" of Galileo's peripatetic opponents:—"Animals that are capable of motion have joints and limbs; the earth has neither joints nor limbs, therefore it does not move. The planets, the sun, and the fixed stars are all of one substance, that is to say, of the substance of stars; therefore they either move together or stand still together. It is to the last degree unseemly to place among the celestial bodies, which are divine and pure, the earth, which is a sewer of filth." "Difesa di Scipione Chiaramonti," Florence, 1633.

moon, according to this description, was said to revolve simply round the earth without any rotation of her own, which is not the way in which her motion would be described at the present day. Accordingly, in stating the earth to have a revolution round the sun combined with a rotation about an axis, Copernicus would have implied that that axis continuously changed its position in space so as to be always in the same direction relatively to the sun. To indicate that as a matter of fact the position of the axis with regard to the sun varied, but remained the same with regard to space, Copernicus had to combine with his two chief motions a third one of annual rotation.

This third rotation was therefore a complication only introduced by confusion in geometrical thought. That the actual state of things is quite simple is illustrated by Salviati by a reference to the motion of a ball floating in a basin of water. If the basin be held in the hand, the ball floating at or near the centre, and the experimenter turn round steadily on his feet, holding the basin in front of him, the ball remains in a position which is unaltered with reference to the walls and furniture of the room; although with reference to the man supporting the basin, it might be said to have spun once completely round. And so with regard to the annual rotation spoken of by Copernicus, Salviati says: "What other is the earth than a globe librated in tenuous and yielding air? That which you think to be a revolution in itself, you will find to be a not moving at all, but a continuing to

be altogether immovable in respect of all that is immovable."

It is here that he speaks so approvingly of the labours of his great English contemporary, William Gilbert of Colchester.[1] He explains Gilbert's theory of the earth as a huge magnet, and develops it, mentioning incidentally some observations and experiments of his own on magnetic phenomena—notably on the increased power of magnets when suitably provided with armatures.

The attractive and repulsive properties of magnets reminded Simplicio that in considering the causes of natural phenomena, some effects are attributed to sympathy which is an agreement and mutual appetency between things having the same qualities, while other effects are due to antipathy when things naturally repel and abhor each other.

"And thus," cuts in the wag, Sagredo, "with these two words they are able to give a reason for a great number of effects which we see, not without admiration, to be produced in nature. But it strikes me that this mode of philosophising is not unlike the style in which one of my friends used to paint. On his canvas he would write with chalk: here a fountain with Diana and her nymphs; here some harriers; in this corner a huntsman with a stag's head; the rest may be a landscape of wood and mountain; and what remains to be done may be put in by the colour-

[1] "I glorify," says Salviati, "I admire, and I envy this great author his marvellous conception of the earth as a magnet." Quite at the end of this "Day" Gilbert and his opinions are again referred to. See p. 59 *ante*.

man. Thus he flattered himself that he had painted the story of Actæon, having contributed nothing towards it beyond the names!"

The fourth "Day" of the Dialogue is devoted entirely to an examination of the cause of the tides, and is a development and extension of his letter on the same subject to Cardinal Orsini, 1616. It is a singular circumstance that the argument, upon which Galileo mainly relied as furnishing a physical demonstration of the truth of the Copernican theory, rested on a misconception. The ebb and flow of the tides, he said, are a visible effect of the terrestrial double movement, since they are the combined result of (1) the earth's daily rotation, and (2) the inequality of the absolute velocities of the various parts of the earth's surface in its revolution round the sun. To this notion he attached capital importance, and he ridiculed Kepler's suggestion (which, however, was nearer the truth) that the attraction of the moon was in some way concerned in the phenomenon. That the influence of the moon was paramount had indeed been recognised in ancient times, but a scientific explanation in detail was not to be expected until the law of universal gravitation had been fully realised.

This last part of the dialogue is therefore of little value, and may be passed over in considering the discussions of the first three "Days." The chief work of the dialogue was to establish the Copernican theory; which, first promulgated in the days when human vision was unaided, had been found by Galileo to be supported by all

evidence that could be gathered by means of his new invention. The problem—if it may be still said to exist—takes a slightly different form at the present day. So far are we now from the pre-Copernican theory of a fixed earth, that we look upon no single object in the whole universe as fixed. The sun itself has its motion amongst the other visible stars; the present direction and rate of that motion are roughly known. Accordingly, the alternative which offered itself to the controversialists of Galileo's day, that either the sun or the earth was stationary, does not concern us; both of the bodies are moving. They move, however, in such a way that the motion of the sun is sensibly uniform, while the earth and the other planets can only be reasonably spoken of as travelling around him while he with his family of satellites is advancing through space.

With this understanding as to what is meant when we speak of the sun, though not stationary, being the centre of the planets' motions, it need scarcely be mentioned that the Copernican theory has acquired, since the days of Newton, an enormous mass of evidence, which in a work of the present type it would be out of place to discuss. But whereas Copernicus and Galileo made it a question practically for common-sense to choose between the simple and the geometrically complex, dynamical evidence has now made any alternative to the simple explanation not only difficult but altogether beyond comprehension; the main points of the Copernican doctrines are proved as absolutely as anything in science can be proved.

This beautiful volume now so forgotten, of which we feel we have given an inadequate idea, is not simply a treatise on astronomical and physical science—a powerful plea for Copernicanism in a country and at a time when all science was "vehemently suspected"; it is a book worthy of Socrates—a book which ought to be studied by those who love free observation and experiment, free discussion and circulation of ideas—in a word, freedom of thought, as the first essential to the progress of science and of our common humanity. In the words of Professor Playfair:—

"One forms a very imperfect idea of Galileo from considering the discoveries and inventions only, numerous and splendid as they are, of which he was the author. It is by following his reasonings and by pursuing the train of his thoughts in his own elegant though somewhat diffuse exposition of them that we become acquainted with the fertility of his genius—with the sagacity, penetration, and comprehensiveness of his mind. The service which he rendered to real knowledge is to be estimated, not only from the truths which he discovered, but from the errors which he detected—not merely from the sound principles which he established, but from the pernicious idols which he overthrew. The Dialogues on the Two Systems are written with such singular felicity that one reads them at the present day, when the truths contained in them are known and admitted, with all the delight of novelty, and feels one's self carried back to the period when the telescope was first directed to the heavens, and when the earth's motion with its train of consequences was proved for the first time. Of all the writers who have lived in an age which was only emerging from ignorance and barbarism, Galileo has most

entirely the tone of true philosophy, and is most free from the contamination of the time in taste, sentiment, and opinion."[1]

[1] "Playfair's Dissertation," Supp. "Ency. Brit.," 7th Ed. The Dialogues occupy the whole of vol. i. in Albèri's edition of the Works of Galileo, 1842-56, and two-thirds of vol. vii. of Favaro's edition. An English translation was brought out by Thomas Salusbury in 1661.

# CHAPTER XII

## PUBLICATION OF THE DIALOGUES—GALILEO AND THE INQUISITION

### 1632-1633

By the beginning of January 1632, the printing of the Dialogues was so far advanced, that on the 3rd Galileo was able to inform his friend Cesare Marsili at Bologna that the work would be ready in ten or twelve days. It did not, however, appear till February. On the 22nd of that month Galileo presented copies to the Grand Duke (his former pupil) to whom the work was dedicated, and to other members of the Medici family. Next day he sent thirty-two copies to Marsili; and had a number handsomely bound for friends and patrons in Rome, but they could not be despatched, owing to the continued prevalence of the plague. Indeed, it was not till May that two unbound copies reached the Eternal City. One of these came into the hands of Cardinal Francesco Barberini (the Pope's nephew), who lent it to Castelli. The latter writing to Galileo, 29th May, expressed his admiration for the work which surpassed all his expectations.[1] Shortly afterwards, Conte Filippo Magalotti, Galileo's friend

[1] In a previous letter, 26th September 1631, the good Father vowed that when the book appeared he would read no others than it and his Breviary.

and, from his relationship to the Barberini family an influential personage, imported eight copies, and, at the author's request, presented one each to Cardinal Antonio Barberini, the Pope's brother; Niccolini, the Tuscan Ambassador; Father Riccardi the Press Censor; Mgr. Serristori, Counsellor of the Inquisition or Holy Office; and the Jesuit Father, Leon Santi.

While these copies were being eagerly read in Rome, and passed from hand to hand, the book had been circulating in all parts of Italy, in spite of the obstacles to communication caused by the plague. The applause with which it was received by all men of independent minds was tremendous; but in this pæan of praise there was one solitary note of warning—a note which would probably have been unheeded even if it came in time. Paolo Aproino, having read a MS. copy which Galileo had sent to Micanzio at Venice, begged his friend to write and advise the author to pause ere he printed a book containing such startling doctrines. Micanzio thought it better that Aproino should himself write, which he did on 13th March—a month too late. Aproino's advice was to send MS. copies to the public libraries in the capitals of Europe, with permission for copies to be made by those who might wish to have them. This would prevent the dissemination of his revolutionary doctrines amongst the ignorant and ill-disposed who would only use them as a weapon for his destruction, while as to the enlightened and unprejudiced, no one would grudge the expense of a written copy of such a precious work.

Great as was the applause on the one side, so on

the other side was the consternation which the book created among the followers of the old school of thought. The educated world of Italy was then divided into two hostile camps—that of Aristotle and Ptolemy on the one side; and that of Copernicus, Galileo, and Kepler on the other. In the first were to be found blind worship of authority, and unquestioning adherence to ancient doctrine; in the second, freedom of thought, research, recognition of demonstrated truths—in a word, progress. As was to be expected, the first-named party was the most numerous and noisy, and it was reinforced by all those who opposed the innovators from interested motives. Foremost amongst these were the members of the Order of Jesus. They claimed for themselves the monopoly of instruction, and the first rank in the learned world, and were jealous of all intruders. Galileo was therefore in every way inconvenient to these people. Besides, had he not measured swords with distinguished members of the Order, as Fathers Scheiner and Grassi and (unforgivable offence) had he not worsted them? And now his Dialogues appeared in which some old sores are re-opened; this revolutionary book must be suppressed at all costs, and with it its detested author.

Father Riccardi, the censor, was the first to announce the coming battle. One day early in August he remarked to Conte Magalotti, "the Jesuits will now persecute Galileo with the utmost bitterness."[1] It is important to establish this fact. Scheiner in a conversation with Torricelli would

[1] Letter, Magalotti to Guiducci, 7th August 1632.

say little about the Dialogues, he found the digressions tedious (and no wonder, for some of them referred to himself), he did not wish to say much on the subject, but, he significantly added, "Galileo has treated me very badly."[1] Then Scheiner himself, writing to Gassendi of Paris, 23rd February 1633, says :—

"In these Dialogues the author has made null all my mathematical researches, and has laid violent hands on my 'Rosa Ursina,' on my discovery of the annual movement of the Sun-spots, and of that of the sun himself. I am preparing to defend myself and the truth."[2]

Before the date of his conversation with Magalotti just mentioned, it came to the ears of Riccardi, that some "ill-disposed persons" were trying to discover something in the book which could form the basis of an accusation against its author; they found something on the engraved title-page! The words "Dialogo di Galileo Galilei, Linceo, al Ser$^{mo}$. Ferd. II Gran. Duca di Toscana" are printed on the field of a pavilion, with the five *palle* or balls, the armorial bearings of the Medici, and surmounted by the Grand Ducal crown. Below, on the shore of a sea stand three persons disputing—Aristotle, Ptolemy, and Copernicus, the two latter having their names printed on the edge

[1] Letter, Torricelli to Galileo, 11th September 1632.

[2] "The Rosa Ursina" was published in 1630, and was a fierce attack on Galileo personally. No direct answer was made, but in several passages in the Dialogues the book received some hard knocks, as Scheiner intimates in the above extract. This Jesuit, if not the leader of the new crusade against Galileo, was certainly one of the foremost and most relentless of his enemies. For further proof of the complicity of the Jesuits, see pp. 284 and 342 *infra*.


*Copia fedele del Rame inciso da Stefano della Bella*

Title-Page of Dialogue of 1632.

[*To face p.* 266.

of their mantles. At their feet is the device of three dolphins, surrounded by a narrow band, bearing a motto and the monogram $\overset{\text{G B}}{\text{L}}$—the whole being the business sign of the printer, G. B. Landini. This title-page was impugned as not having been submitted for ecclesiastical approval, and particularly they expatiated, with more malice than wit, upon the meaning of the three dolphins' device; it reminded them so much of the three bees of the Papal arms! It was a great relief to Riccardi's mind when Magalotti pointed out that the same device appeared on nearly all the works which issued from the Landini press at Florence, where also this book was printed.

This shot, then, had not taken effect, and the "ill-disposed persons" had to find some other mode of attack. They now brought against the author the two-fold charge (1) that the preface was printed in different type from the rest of the book, which was true, but was simply a necessity of the printer;[1] and (2) that some weighty arguments against the Copernican theory, which the Holy Father had brought forward in conversation with Galileo in 1624, were not in the printed book, although it was a condition that they should be. This charge was *not* true, for the "weighty arguments" were in reality only one, and this, as we have seen, was duly introduced at the end of the work, where it

[1] After receiving the *Imprimatur* for Rome, and foreseeing no further difficulty, Galileo had begun to set up his book, and by 16th August 1631 about one-third of the volume was in print. Hence the preface, which went to press later, had to be printed on a separate sheet, and in different type.

was appropriately put into the mouth of Simplicio, who gave it as an argument which he had from "a very eminent and learned personage" (p. 248 *ante*).

Foiled again, the assailants now fastened on the very natural circumstance that the "weighty argument" was placed in the mouth of Simplicio, the defender of Ptolemy. Knowing the Pope's weaknesses, vanity, arrogance, and ambition,[1] they made him believe that by Simplicio—the simpleton—no other was intended than Urban VIII. himself! One would have thought this impossible with this shrewd old man (seeing the friendly relations which up to this had subsisted between him and Galileo), but it is beyond all doubt that it was so, and it put his Holiness in a terrible rage. While in this condition they easily persuaded him that the Copernican doctrine ran counter to the dogmas of the Catholic faith, and after this it was not difficult for them to show that the Dialogues, which were a defence of that doctrine under a flimsy veil, would do incalculable injury to the Church. Having thus worked on the Pope's fears, they easily persuaded him that in this work Galileo had again, though under concealment, dared to interpret the Scriptures; he was therefore rebellious; and he was further deceitful in that he obtained the *Imprimatur* by cunning devices.

[1] He wished to be thought another Leo X. So vain was he that he caused documents to be forged proving his family to be one of the oldest and most noble of the Florentine stock. He is noted in history for three things: (1) excommunication of all who took snuff in churches, 1624; (2) persecution of Galileo, 1632-42; and (3) the foolish campaign against the Duchy of Castro, "Guerra di Castro," 1642-3.

Although the safety of the Church and the vindication of its decrees were the ostensible reasons for the subsequent proceedings against Galileo, it would not be far from the truth to say that revenge for an assumed personal insult was the primary and determining factor.[1] Without this personal motive the storm may have blown over as other and equally threatening ones had previously done. Urban VIII. and many of the high dignitaries of the Church were, if anything, Copernicans (they certainly were not Ptolemaists, and hardly even peripatetics),[2] while others were indifferent and cared little one way or the other. As regards the Pope himself, we have seen his letter of 20th April 1613, to Galileo, praising so highly the book on Sun-spots—the very work on which the prohibition of 1616 was based. We have also seen how delighted he was with "Il Saggiatore" and the "Reply to Ingoli," in both of which the Copernican theory is defended; and, finally, we have Urban's own statements (1) that the Copernican doctrine is not heretical, but only rash, and (2) that if it rested with him, the decree of 1616 would never have been issued. All this seems to show that, if the question of a personal insult had not arisen, the Dialogues might have weathered the storm, or, at the worst, been put on the Index, as was the book of Copernicus in 1616, "until corrected."

While these things were passing secretly at

[1] See Galileo's letter to Micanzio, dated 26th July 1636, where he says the making game of the Pope, as his Holiness had been persuaded, was the primary cause of all his troubles.

[2] See Albèri, vol. xvi. p. 326.

Rome, Galileo in Florence gave himself up to unmixed delight at the great success of his book. His friends, such as Castelli, Cavalieri, Micanzio, Campanella, and others, expressed in letters their unbounded admiration. Thus, Micanzio, writing on 3rd July, says:—

"I had hardly time to devour your book when it was taken from me and lent from one to another. To-day, no sooner do I get it back by main force, than I am obliged to send it to the Commissary Antonini at Verona, one of our cleverest men, and one who admires you above all the *literati* of the age."

Not one of all his friends who praised the book so highly had any foreboding that it was soon to bring its grey-headed author before the bar of the Inquisition, and least of all Galileo himself. He, of course, expected the usual opposition from his "scientific" opponents, and was prepared to meet it; but he considered himself secure from anything like conflict with the ecclesiastical authorities.

One day, about the middle of August, the first thunder-clap broke over Galileo. His publisher Landini received instructions, though for the time only provisional, forbidding the further sale of the Dialogues.[1] The second clap, which followed in a few days, was the news of the appointment of a special commission at Rome by order of the Pope, and under the presidency of his nephew, Cardinal F. Barberini, to examine the book and report. It was composed of Jesuits, Dominicans, and Theatins,

[1] It appears this step was taken on the report of the Jesuit Father Inchofer, one of the counsellors of the Inquisition.

"not one of whom had any knowledge of mathematics, or familiarity with abstruse speculations," all endeavours of Niccolini and others to get friends of Galileo, such as Castelli and Campanella, put on the board being vetoed by the Pope.[1] Galileo now appealed to his Sovereign for protection, and, on 24th August, the chief Secretary Cioli wrote to Niccolini that the Grand Duke was greatly surprised to learn that a book which had been laid before the supreme authorities at Rome by the author in person; had been carefully read there again and again, as well as afterwards at Florence; had, at the author's request, been altered by these authorities "as seemed good to them"; and finally had received the *Imprimatur* for Rome and Florence, should now, after two years, be considered suspicious, and be prohibited. His Highness was of opinion that this opposition must be directed against the person of the author rather than against his book, so often and so carefully read and revised by the proper authorities. In order, then, to inform himself of the merits or demerits of his servant, his Highness desires that that which is granted in all disputes and before all tribunals should be permitted to the accused, viz., to defend himself against his accusers. The Grand Duke, therefore, requests that the accusations may be sent to Florence, so that the author, who stands firmly on his innocence, may see and answer them.[2]

On the same day on which this despatch left

[1] See letters of Campanella to Galileo, dated 31st August and 25th September 1632.

[2] The original draft of this despatch, much of which is in Galileo's handwriting, is now in the National Library, Florence.

Florence a mandate was issued from Rome, confirming the provisional prohibition of the Dialogues, and ordering Landini to send all copies in stock to Rome. He replied that the edition had been sold out, and, consequently, he had no copies to send.

On receipt of the Grand Duke's orders, Niccolini hastened to carry them out, but met with more opposition than either he or his master had expected. The Pope received him in such a way that he thought the world must be going to pieces, and at the first mention of Galileo's name the Holy Father interrupted him bluntly: "Your Galileo has dared to meddle with things that he should have left alone—in fact, with the most important and dangerous subjects that can be stirred up in these days." On the Ambassador remarking that the book was published with the approbation of the Church, the Pope angrily replied that both Galileo and his secretary, Ciampoli, had deceived him on that matter. The censor, Riccardi, had also deceived him, "but," he added, "the latter had been himself deceived, for he had been induced by fair speeches to approve the book, and by more fair speeches to allow it to be printed in Florence." Thinking to save the book from condemnation, Niccolini hinted that it was dedicated to the Grand Duke. "What of that?" was the reply, "I have prohibited books which bear my own name on the title-page." The Pope added, "in charging a special commission to examine the book, instead of handing the affair at once to the Inquisition, I have followed a course

best for Galileo's interests—he who did not fear to make game of me." Niccolini then begged that the accused may know the charges against him and have an opportunity of justifying himself, to which Urban curtly answered: "Galileo knows well enough in what way he has transgressed. In these matters of the Holy Office nothing is ever done but to pronounce judgment, and then summon to recant."[1]

Two letters from Magalotti, who was usually well informed, arrived at the same time as this despatch, both dated 4th September, one to Mario Guiducci, the other to Galileo. Magalotti's news was on the whole reassuring. From the opinions of persons present at the sittings of the commission, he thought he could say that matters would not go so far as condemnation of the Copernican doctrine "by supreme authority."[2] He thought with Riccardi that they would not entirely prohibit the Dialogues, but only "correct" them, so as to sustain the decree of 1616. He advised (as Niccolini also had done) the utmost patience and circumspection, and to confer with Cardinal F. Barberini rather than with the Pope himself, "for reasons which it is not necessary to detail."

The special commission, after a month's session,

[1] Letter, Niccolini to Cioli, 5th September 1632. Here the Holy Father shows his hand, Galileo dared to make game of him. The poison had taken effect.

[2] It never did, in fact, come to this; for the "supreme authority" is the Pope speaking *ex Cathedra*, or an Œcumenical Council. The proceedings of 1616 were not endorsed by "supreme authority," and we shall find this to be the case in the present proceedings also.

submitted a long report to the Pope. The document begins with a statement of the course of the negotiations for the printing of the Dialogues, and then come three indictments against the author :—

1. Galileo had transgressed orders in deviating from the hypothetical standpoint, by maintaining *decidedly* that the earth moves and that the sun is stationary.

2. He has erroneously ascribed the phenomena of the tides to the stability of the sun and the motion of the earth, which are not true.

3. He has been deceitfully silent about the command laid upon him in 1616, viz., to relinquish altogether the opinion that the sun is the centre of the world and immovable and that the earth moves, nor henceforth to hold, teach, or defend it in any way whatsoever, verbally or in writing.

Then follows the remark: "It now remains to be considered what proceedings are to be taken against the person of the author, and against his printed book." The rest of the document is taken up with an elaboration of the charges against Galileo, and a fuller account of the negotiations for the *Imprimatur*. These need not detain us; but in a final clause, Galileo is specifically charged with having transgressed the order of the Holy Office to relinquish (etc., as per charge (3) above). This, then, was his chief offence; the others "could be corrected if the book was thought to be of any value"; but to deliberately and deceitfully transgress commands, that, evidently, could not be "corrected" or condoned.

Here for the first time the minute of 26th February 1616 is mentioned, as to which Niccolini has something of importance in his despatch of 11th September to Cioli. Reporting an interview with the Master of the Sacred Palace, he says that Riccardi, after advising patience and caution, repeated the old stock complaints, that the Dialogues imperilled the faith, that the author did not confine himself strictly to mathematics, but brought under discussion religion and the Scriptures [which is *not* true], and that the Papal orders as to the preface, end, and hypothetical treatment had not been complied with—an extraordinary assertion for one who had himself certified that they had been complied with. He then confided to the Ambassador as a profound secret "that it had been discovered in the books of the Holy Office that sixteen years ago (it having been heard that Galileo entertained that opinion, and disseminated it in Florence) he was summoned to Rome, and forbidden by Cardinal Bellarmine, in the name of the Pope and the Holy Office, to hold that opinion. And this alone is enough to ruin him entirely." Evidently the paper here hinted at is the minute of 26th February 1616. It will, therefore, be desirable to pause for a moment, and read again our remarks on p. 166, for our account so far of these new proceedings brings out a point there discussed, which we wish to emphasise, viz. that the minute is not true to the spirit of the proceedings. We have seen that the Pope knew all about the process of 1616—in fact, as Cardinal Maffeo Barberini, was an unwilling party to it. If Galileo was then commanded to

relinquish altogether his opinion, and henceforth not to hold, teach, or defend it in any way whatsoever, verbally or in writing, why did Urban VIII. discuss this same opinion with him in 1624? why did he openly approve "Il Saggiatore" and the "Reply to Ingoli"? and why in 1630, when Galileo took his Dialogues to Rome, was he not met with a *non-possumus*, and referred back at once to this rigid prohibition? Clearly, because this rigid prohibition had for him no existence—had no right to exist, for he knew it was not intended that Galileo should be forbidden to hold, teach, or defend his opinion in any way whatsoever, verbally or in writing, *except* in case he refused to be bound by Cardinal Bellarmine's simple admonition—a contingency which did not arise. The minute, therefore, is not true to the spirit of the proceedings, and should properly be treated as non-existent. It is, moreover, of no value in law in that it bears no signatures. To base, then, a charge against Galileo on such a worthless paper convicts his persecutors of *ultra vires*, and shows their determination to punish him at any price, even at the cost of a judicial crime.[1]

Now let us return to our narrative. A few days

[1] The steps of these new proceedings are also against the theory of a forgery with ulterior designs. Were it so, why, during the long and vexatious negotiations about the *Imprimatur*, did not the forgers appeal to it at once, as a bar to granting a licence? Why, immediately on the appearance of the book, did they not accuse Galileo of breaking his solemn promise, and call down upon his head the penalty for disobedience with which the document threatened him? Why have recourse for months to trumpery charges and ignoble stratagems, when they could have played this trump card? Clearly, because its existence was not known to them until the first week in September 1632, when its discovery was a surprise to all, friends and foes alike.

after Niccolini's interview with Riccardi, on the 15th September, the Pope sent word to the Tuscan Ambassador that Galileo's affairs would be handed over to the Inquisition. At the same time the strictest secrecy as to this step was enjoined on both the Grand Duke and Niccolini, with a hint that otherwise they would be proceeded against, according to the statutes of the Holy Office. Niccolini, astounded by this intimation, hastened to the Pope to avert, if possible, the danger of a trial, but his pleadings were in vain. Urban was good enough to say that Galileo was still his friend, but his opinions had been condemned sixteen years before, and were in the highest degree pernicious to the Church. On 23rd September the following order was issued:—

"His Holiness charges the Inquisitor at Florence to inform Galileo, in the name of the Holy Office, that he is to appear in the course of the month of October, in Rome, before the Commissary-General. He must obtain a promise from Galileo to obey this order, which the Inquisitor is to deliver in the presence of a notary and witnesses, but in such a way that Galileo shall know nothing of their presence, so that if he refuse to obey they may bear witness to his contumacy."

This order, which was delivered to Galileo on 1st October, and with which he consented in writing to comply, fairly overwhelmed him, for, from the secrecy maintained in Rome, he was wholly unprepared for any such measure. Scarcely recovered from a complaint in the eyes which had lasted several months, suffering otherwise in health,

and at an advanced age, he was now to go to Rome in the midst of the plague (which had broken out afresh) to appear before the terrible Inquisition. No wonder that he was dismayed, and that in spite of his promise "willingly to obey the order in the course of this month, October," he made every effort to evade it. His deep depression is evident from a long and pitiable letter, of 13th October, to Cardinal Francesco Barberini (the Pope's nephew), sent through the hands of Niccolini:—

"That my Dialogues recently published should find adversaries was not to be doubted, as your Eminence no doubt foresaw. It is in general the lot of all opinions which in one way or another run counter to the accepted doctrines. From the reception of my other works I expected as much, but what I did not expect was that the hate of one or two of my enemies (furious at seeing the lustre of their works tarnished by mine) would be able so to influence my superiors as to make them believe that my works are unworthy of the light of day, and should be stifled. The prohibition of the printing and sale of my Dialogues has been a cruel blow to me, but I am consoled by the knowledge of the extreme purity of my conscience, and by the feeling that I shall have no difficulty in justifying my intentions.

"I will not conceal from your Eminence that the injunction to present myself without delay before the tribunal of the Holy Office has afflicted me profoundly. It is impossible to think without bitterness that the fruits of my labours and studies for so many years (which gave to my name in the scientific world a certain *éclat*) should now be branded as criminal. All this depresses me to such

an extent as to make me curse the time I have devoted to these labours—yes, I regret having given to the world so much of my results. I feel even the desire to suppress, to destroy for ever, to commit to the flames, what remains in my hands. Thus I should satisfy the burning hate of my enemies. These are some of the thoughts which afflict me, and increase the burden of my seventy years; they aggravate my numerous physical sufferings, and cause me persistent insomnia. When to these is added a journey, rendered more painful and dangerous by sundry causes, I am almost certain that I shall not reach the end alive. The desire to live, common to all men, makes me implore the intercession of your Eminence, encouraged thereto by the kindness of heart which distinguishes you, and of which I as well as others have been the recipient. I beg you, then, to represent to the Holy Father my present pitiable situation. . . .

"Whether it be necessary to receive my justification in writing, or by *vivâ voce*, I would point out that there are here in Florence the Inquisitor, the Archbishop, and other learned functionaries of the Church, who would be able, it seems to me, to decide graver causes than mine, and before whom I am ready to appear. It is hardly likely that in a book, which has been carefully examined by the censors, with full power to omit, to add here, to correct there, there should still remain errors so grave that their correction, or the punishment due to them, should be beyond the power of the local authorities."[1]

Before taking action the Ambassador consulted

[1] By the same post Michelangelo, the younger, wrote to the same Cardinal, entreating him, out of consideration for the philosopher's age and infirmities, to try all means to have his affairs settled in Florence. See letter dated 12th October.

Castelli (whom the Grand Duke had appointed as his counsel in this affair) as to the advisability of delivering Galileo's letter to the Cardinal. It was decided to do so, and Niccolini reported that it was received in a very friendly way, with assurances of his Eminence's kindly disposition towards the writer. The letter was discussed by the Holy Office on 11th November, in presence of the Pope; but his Holiness would not grant the prayer, and ordered that the writer must be *compelled* to come to Rome. Niccolini was unwearied in trying to get the affair settled in Florence, but to no purpose. The Pope had seen Galileo's letter of 13th October, but the journey to Rome could not be dispensed with. "Your Holiness," exclaimed Niccolini, "incurs the danger, considering Galileo's age, of his being tried neither in Rome nor in Florence, for I solemnly assure your Holiness that he may die on the way under all these difficulties and anxieties." "He can come very slowly," replied the Pope, "in a litter, with every comfort, but he really must be tried here in person. And may God forgive him for having been so deluded as to involve himself once more in these difficulties, after having been extricated by me from his first difficulties in 1616, when I was Cardinal." Much discomfited and with profound sorrow, Niccolini communicated this decision to Galileo in a letter on 13th November, and in a despatch to Cioli of the same date.

A few days later, 19th November, Galileo was summoned before the Inquisitor at Florence, in accordance with the Papal orders, and was charged

to comply with the mandate to go to Rome in the presence of a notary and two witnesses—a respite of one month being allowed. The appointed time had nearly arrived and no preparations had been made for starting. The Inquisitor sent his vicar to see Galileo and reported the result in a letter to Rome on 18th December:—

"My vicar found Galileo in bed; he was quite ready to set out, but in these times he had no heart for it; besides, just now, owing to a sudden attack of illness he was not in a condition to travel. He has sent me the enclosed medical certificate, so that I have not failed to do my duty."

The certificate, dated 17th December, gives an idea of the physical sufferings of this much-tried man, and is signed by three doctors:—

"We, the undersigned physicians, certify that we have examined Signor Galileo Galilei and find that his pulse intermits every three or four beats, from which we conclude that his vital powers are affected, and at his great age much weakened. To the above are to be ascribed frequent attacks of giddiness, hypochondriacal melancholy, weakness of the stomach, sleeplessness, and flying pains about the body, to which others also can testify. We have also observed a serious hernia with rupture of the peritoneum. All these symptoms are worthy of notice, as under the least aggravation they might become dangerous to life."

Little importance seems to have been attached to this certificate at Rome. Niccolini (26th December) fears that the ecclesiastical authorities at Florence will be ordered to take extreme

measures. Castelli (25th December) urges his old and revered master to set out. But in this, as in all his letters of this period, he shows that he had no idea of the real nature of the proceedings going on. Knowing of no crime committed by his master against the Holy Office, he urged him to set out, because he had the idea that Galileo's persecutors desired nothing better than that he should refuse, in order that they may decry him as an obstinate rebel against Holy Church.

On 30th December the fears of Niccolini were realised. On that day a Papal order was issued to the Inquisitor at Florence, stating that neither his Holiness, nor the Congregation of the Holy Office, could or would tolerate further evasions. It must, therefore, be proved that Galileo's state was really such that he could not come to Rome without danger to his life. A commissioner with a physician would be sent to Florence, who would see Galileo and make a true and trustworthy report on his condition, and if he were in a state to travel the commissioner must bring him a prisoner in chains. If out of consideration for his health, or other danger to life, his coming must be postponed, then as soon as he had recovered, or the danger was over, he was to be brought a prisoner in irons. The commissioner and physician would travel at Galileo's expense, because he had not obeyed the command to appear when his condition would have permitted it.

To avert these extreme measures the Grand

Duke caused Galileo to be informed (11th January 1633) that it was at last necessary to obey the orders of the supreme authorities at Rome, and in order that he might perform the journey more comfortably Grand-ducal litters and a trustworthy guide would be placed at his disposal; he would also be lodged in Rome in the house of the Grand Duke's Ambassador. The pitiful impotence of an Italian ruler of that day in face of the Roman Church is painfully obvious in this decision. The Sovereign does not dare to protect his subject —more, his old and respected tutor, and the greatest philosopher of whom Italy could boast— but gives him up to the dreaded Inquisition, as if he were an alien malefactor. The Venetian republic was the only State in Italy that would have asserted its independence (as it had often done before), and would have refused to hand over one of its officials to the Roman power. Indeed, when these proceedings began, Francesco Morosini of Venice offered to reinstate Galileo in his old chair at Padua on any conditions that he chose to make, and to print his Dialogues in Venice. Galileo was now suffering a bitter penalty for the mistake of 1610 in deserting Padua.[1]

20th January 1633 was the day fixed for Galileo's departure. On the 15th he addressed a long letter to his friend Elia Diodati of Paris, a celebrated jurist and advocate. It begins with

[1] This old friend of Galileo was a power in Venice. Francesco Morosini, the son, was the famous Captain-General of the Republic and conqueror of the Morea in the war against the Turks 1684-94; hence his name in history, Il Peloponesiaco. He was elected Doge in 1688, and died fighting at Nauplia in 1694, aged seventy-six.

comments on the astronomical treatises of Morin and Fromond which Diodati had sent him. He then goes on to speak of his own unhappy circumstances.

"Many years ago when the stir about Copernicus was beginning, I wrote a letter [to the Grand-Duchess Cristina], in which, supported by the authority of numerous Fathers of the Church, I showed what an abuse it was to appeal so much to Holy Scripture in questions of natural science. As soon as I am in less trouble I will send you a copy. I say in less trouble, because I am just now going to Rome, whither I have been summoned by the Holy Office, which has already prohibited the circulation of my Dialogues. I hear from well-informed persons that the Jesuit Fathers have insinuated in the highest quarters that my book is more execrable and injurious to the Church than the writings of Luther and Calvin. . . .

"My publisher is disconsolate, the prohibition of the book has caused him a loss of more than 2000 scudi, for the sale of the first edition and a second twice as large was assured. As for myself, in the midst of so many afflictions and embarrassments that which afflicts me most is the thought that I must renounce my other works—especially my work on Motion—or at most, that I cannot hope to see them appear during my lifetime."

On 20th January, this man of woes set out on his terrifying journey in a Grand-ducal litter. How different the circumstances from those of the same journey eight years before! Prince Cesi, his entertainer at Acquasparta, was dead; his own health, never good for many years past, was now

a chronic cause of suffering; and his eyesight had begun to fail. Not only was the time of year unfavourable (January—February being the season when the biting *tramontana* is most frequent), but the country through which he had to pass was bleak and inhospitable, and its inhabitants, always wild as the winds that howl across its wastes, were now made more wild and desperate by the ravages of the plague. At the frontier post, Ponte Centino, he was obliged to halt twenty days on account of quarantine. From each halting place the poor old man had written to his daughter, the one soul on earth to whom he knew he could turn for sympathy and consolation, and she, sweet consolatrix, what can she say in reply? After expressing her grief at his being detained so long in a wretched habitation, deprived of every comfort, she entreats him "to keep up his spirits, and to put his whole trust in God, who never forsakes those who trust in Him." What else could she say? although at the moment she knew that some of God's ministers on earth were intent on his persecution for the greater honour and glory of His kingdom.

On the afternoon of 13th February Galileo arrived in Rome and was warmly received at the Tuscan Embassy. On the next day Niccolini informed the Grand Duke of his arrival, and that next morning he would introduce him to Cardinal F. Barberini, and beg that he be permitted to remain at the Embassy instead of being locked up in the prison of the Holy Office. This favour was at once granted provisionally, and afterwards

officially confirmed, with injunctions to keep indoors, and to see no one until further orders. Beyond this, and to Galileo's surprise, no official notice was taken of his presence for some time. Writing to Cioli on 19th February, he says:—

"As to the situation of my affairs I can tell you nothing. However, to judge by what has passed, it appears to me, as well as to the Ambassador and his staff, that the storm which menaces me is a little calmed—at least in appearance, so that I do not give way to discouragement, as if shipwreck were inevitable, and all hope of reaching port were gone—the more so as following the instructions of my master, Ariosto:

'I make sail with modesty
Amidst the raging billows.'

"I keep to the house, not thinking it proper to go out as if I wished to show myself. Up to the present no official steps have been taken. One of the members of the Congregation has called on me twice, conversing in the most agreeable manner, and giving me an opportunity to explain myself, and to show my submission, always sincere, to the Church—to which, as far as I could see, he listened with satisfaction. If his visits, as may be supposed, were made with the knowledge or even by order of the Congregation, I may consider them as the beginning of a milder treatment, far removed from the cords, chains, and dungeons, with which I was menaced. I find another consolation in the kindly sentiments towards me expressed by many influential personages. As it appears to me easier to confirm the latter in their good opinions than to convert those who are unfavourable, I think, with the Ambassador, that letters from our august master to Cardinals Scaglia

and Bentivoglio[1] would be very useful, and if you agree with us I beg that you will obtain me this favour."

The member of the Congregation here referred to was Mgr. Serristori. Niccolini thought that the object of his visits was to discover the present sentiments and defensive arguments of the dreaded dialectician, and was inclined to think that they boded well.

"I think," he writes, "I have succeeded somewhat in cheering up the good old man by what I have told him of the steps being taken in his favour. But he constantly expresses his wonder at all this persecution."[2]

The same cheerful confidence is expressed in Galileo's letter of 25th February, to Bocchineri:—

"The Ambassador thinks he perceives each day a diminution in the irritation against me, and so does Father Castelli, who is for me a zealous and indefatigable advocate. We learn, in short, that the many and serious accusations against me are reduced to one, and that the others have been allowed to drop. Of that one I shall be able to clear myself without much trouble, when the grounds of my defence have been heard. Little by little I am bringing these to the ears of some of the higher officials, who can neither refuse absolutely to listen to my explanations, nor to leave them entirely without reply. So we conclude that in the end a favourable issue may be hoped for.

"I keep strictly to the house which appears to me and my friends to be the correct thing. The Cardinal Barberini has given me the same

[1] Bentivoglio was a pupil and disciple of Galileo in Padua.

[2] Despatch to Cioli, 19th February 1633.

counsel, not *ex officio* but, as he says, as a friend. As I have already told you, not a word official has yet come from the tribunal. One of the counsellors, my friend and protector for many years, has visited me a couple of times and furnished me an occasion to explain myself freely on several points, and to show him some papers drawn up by me for this case, with which he declared himself satisfied.[1] We suppose, not without reason, that these visits have been made with the knowledge, and, perhaps, even by order of the superior authorities, with the object, perhaps, of getting some general information. If so, they could not have adopted a better course in my interests.

"The deprivation of exercise for the last forty days begins to be prejudicial to me, for as you know I find exercise necessary for my health. My digestion especially is troubled; viscous matters accumulate; and for the last three days painful twitchings in the limbs have prevented my sleeping. I hope that a severe dietetic regimen will effect a cure. Some days ago I told you how useful would be letters from his Highness to Cardinals Bentivoglio and Scaglia, who, as I am privately informed, are well disposed towards me. If we find in the Congregation one or two members ready and resolute to defend innocence and the truth, we may hope that their voices will suffice to impose silence on those inimically inclined. Therefore I beg you to procure these letters through the medium of Signor Cioli.

"*P.S.*—Please communicate this letter to my daughters and Vincenzio."

Niccolini's despatch to Cioli of two days later

[1] For what was probably Galileo's line of defence at this time, see Favaro's "Nuovi Contributi alla Storia del Processo di Galileo" (*Atti del R. Istituto Veneto*, 1894-95), an admirable piece of constructive evidence.

(27th February) explains the nature of this chief accusation:—

"Although I am unable to say precisely what stage Galileo's affairs have reached, or what may happen next, as far as I can learn the main difficulty consists in this—these gentlemen maintain that in 1616 he was commanded neither to discuss the question of the earth's motion, nor to converse about it. He says, on the contrary, that these were *not* the terms of the injunction, which were that that doctrine was not to be held or defended. He considers that he has the means of justifying himself, insomuch as it does not at all appear from his book that he does hold or defend the doctrine; or that he regards it as a settled question, as he merely adduces the reasons *hinc inde*. The other charges appear to be of less importance and easier to get over."[1]

On the same day the Ambassador in a long audience officially announced Galileo's arrival, and expressed the hope that his Holiness would now be convinced of his reverence for things spiritual, especially in reference to the matter in hand. The Pope replied that he had shown Galileo a special and unusual favour in allowing him to stay at the Ambassador's house instead of remitting him to prison. Niccolini suitably acknowledged the great favour, and then went on to urge that in consideration of Galileo's age and bad health the trial may be hastened. Urban replied that the proceedings of the Holy Office were usually tedious, and he really did not know whether so speedy a termination could be looked for. They were still engaged with the preliminaries.

[1] See remarks on this point, p. 274 *ante*.

As to the nature of these preliminaries nothing certain could be learnt, but Galileo continued to hope for the best. In a letter to Geri Bocchineri (5th March), after acknowledging receipt of the letters for Cardinals Bentivoglio and Scaglia which had, as he thought, a good effect, he goes on to say:—

"As to my affair, it goes on silently as from the first day. If one can judge by rare signs, the accusations have lost much of their gravity, and already some have been entirely dropped by reason of their evident insignificance, which is a good presage for those that remain."

A fortnight later, on 19th March, he wrote in a similar strain to Cioli:—

"The same silence continues to be observed in my affair, and nothing more can be ascertained than what the Ambassador has picked up here and there, and which is sufficiently vague. My indefatigable defender, Benedetto Castelli, has also been secretly informed, but in the same general terms, that the proceedings have taken a slightly more favourable turn, thanks to the letters of his Highness. Therefore, as the Ambassador will tell you, the same intervention with the other Cardinals, members of the Congregation, would be of great utility, the two to whom letters have already been addressed having expressed themselves in this sense. I pray you then to obtain for me from his Highness this additional favour."

In spite of the gravity of the situation, it would seem that Galileo was careful to write to his daughter in such a strain as to calm her

anxiety throughout this weary time. Therefore, on 13th March, she writes back :—

"As matters are going on so favourably I will not mind though your return be delayed, for indeed my being disappointed is a small thing, if staying where you are redounds to your reputation and advantage; and what makes me still more easy is to hear how honourably you are treated by those excellent gentlemen, and in particular by her Excellency the Ambassadress. I am well now because my mind is at rest. Nevertheless I do not cease praying for you."

On the same day (13th March) on which Maria Celeste was thus hopefully writing, Niccolini had an audience of the Pope, in which he was informed that it would be necessary to summon Galileo to the Holy Office on the eve of the trial. It was the usage and could not be departed from. Again, the Ambassador pleaded the accused's bad health, great age, and the willingness he had shown to submit to any penalties; but Urban replied it would not do to order otherwise. He regretted that Galileo "who had been his friend, with whom he had often held confidential intercourse, and eaten at the same table," should be subjected to these annoyances, but it was in the interests of religion.

Notwithstanding this intimation, days and weeks passed, and yet Galileo was not summoned before the Inquisition. All this time, as we see from his letters, he was entertaining confident hopes of some favourable issue; but, as a matter of fact, there were no grounds for this belief.

Neither he nor his indefatigable friends, Castelli and Niccolini, could learn anything definite. The members of the Congregation, who alone could have given information, kept the secrets of the Holy Office very closely, as indeed they were bound to do under the severest penalties to themselves. Thus the month of March passed by; April was come, and with it the storm which had been so long threatening.

On the 7th, Niccolini went to Cardinal Barberini by invitation, and was informed, on behalf of the Pope and the Congregation, that Galileo must appear before the Holy Office, and, as it was not known whether the case could be settled at a single sitting, it might be necessary to detain him. Once more the Ambassador urged consideration for his age and health (he had again been ill and confined to bed), and begged the Cardinal to consider whether it would not be possible for him to return every evening to sleep at the Embassy. To these appeals his Eminence replied that such a permission was not to be expected. He promised, however, that every comfort would be afforded him in the buildings of the Holy Office; that he would neither, as was customary with accused persons, be treated as a prisoner, nor be placed in a cell; but he would have good rooms, and, perhaps, his doors would not even be locked. Niccolini reported this notification to Cioli on 9th April, adding the following interesting details:—

"This morning I also had a conversation with

his Holiness, who again gave vent to his displeasure that Galileo should have discussed this subject which appears to him to be very serious, and of great moment to religion. Signor Galileo thinks, nevertheless, that he can defend his statements on good grounds; but I have warned him to refrain from doing so, in order not to prolong the proceedings, and to submit to what shall be prescribed to him to believe respecting the motion of the earth.[1] He has fallen into the deepest dejection, and since yesterday has sunk so low that I am in great concern for his life. I shall beg that a servant may be allowed him, and as much comfort as the place will admit of. Meanwhile, we are all doing our best to console him and to help him through our recommendations to the most friendly disposed members of the Congregation; for truly he deserves every possible kindness that can be shown him. I cannot describe to you the grief of the whole house, for every one here loves him exceedingly."

From this, then, we learn that up to 8th April Galileo was still intending to defend himself and his opinions, and that it was only on the earnest entreaty of the Ambassador that he gave up all idea of opposition, and resolved upon entire submission.

[1] In a previous despatch of 19th February, he says: "I have advised Galileo to be always ready to obey and to submit to whatever was ordered, for this was the only way to allay the irritation of one who was so incensed, and who treated this affair as a personal one." Clearly, this "one" was no other than Urban VIII.

## CHAPTER XIII

### GALILEO AND THE INQUISITION—(*continued*)

### 1632-1633

On 12th April 1633, Galileo appeared for his first examination before the Commissary-General of the Inquisition, Father Firenzuola, and the Procurator-Fiscal, Father Sincero. In all his answers he is actuated by one idea—that of shortening the proceedings and averting severe measures by submissive acquiescence. According to the rules of the Holy Office, an oath is administered to the accused that he will speak the truth, and he is then asked whether he knows or conjectures the reason of his citation. Galileo replied that he supposed he had been summoned to give an account of his last book. After being asked if he acknowledged the work shown him, "Dialogo di Galileo Galilei, Linceo," as his, and his reply in the affirmative, the examiners led him back to his visit to Rome in 1616, and to what then happened in the matter of the prohibition. His answers show that he only knew of Cardinal Bellarmine's admonition, as recorded in his certificate of 26th May 1616. That a "command" in more stringent terms was issued

to him (as the Inquisitor asserts) he is not aware, but, true to his resolve of submissiveness, he says again and again: "It may be so, but I do not remember it." He is then told that this "command" was to the effect that he must not hold, defend, or teach, in any way whatever, verbally or in writing, the doctrines of Copernicus. Galileo, who hears for the first time the exact terms of this further injunction "not to teach in any way whatever, verbally or in writing," is amazed, but is still submissive. "It may be," he answers, "that this injunction was also there, but I do not remember it." He then appeals again to Cardinal Bellarmine's certificate, "in which," he says, "there is no mention of this further injunction which has just been made known to me."

After trying by every artifice to get from him an admission that this further injunction was laid upon him, and after his declaring for the fifth time that he did not remember any "command" beyond the admonition of Cardinal Bellarmine, the Inquisitor asked whether he had received any permission to print his Dialogues, and if in the negotiations he had mentioned the "command" aforesaid. He replied: "I did not say anything about it when I asked for the *Imprimatur*. I did not think it necessary to say anything, because I did not consider that in writing the book I was acting contrary to, far less disobeying, the command 'not to hold or defend' the aforesaid opinions. I have neither maintained nor defended the opinion that the earth moves and that the sun is stationary, but

have demonstrated the opposite, and shown that the arguments of Copernicus are weak and inconclusive." With this answer the first sitting of this memorable trial closed. Silence on matters connected with the proceedings having been imposed on oath, Galileo was led to his apartments in the private quarters of the Procurator-Fiscal, where he received kind and considerate treatment. Writing to Bocchineri on 16th April, he says :—

"Contrary to custom, three large and comfortable rooms have been assigned to me, with permission to walk about in the spacious corridors. My health is good, for which, next to God, I have to thank the great care of the Ambassador and his wife, who have a watchful eye for all comforts—far more than I require."

A servant was allowed to remain with him, Niccolini was permitted to send in his meals, and no obstacle was opposed to his free correspondence with the kind Ambassador.

In their treatment of Galileo personally (unprecedented for its considerateness), throughout the whole of these proceedings, the Inquisition did homage to his genius. Since the establishment in 1215 of this dreadful tribunal, no prisoner had ever been treated with such leniency; for princes, prelates, and noblemen, all had been consigned to the secret dungeons from the very commencement of their trial. The Pope himself in an interview with Niccolini (reported in his despatch to Cioli, 27th February 1633) said, *àpropos* of this point, that Galileo was treated as a privileged person, and reminded the Ambassador that in the recent case of a gentleman of

the princely house of Gonzaga far different measures had been taken, that he had been not only carried to Rome by officers of the Inquisition, but was kept closely imprisoned for a long time before judgment was pronounced.

On 15th April, three days after the first examination, three counsellors of the Holy Office, Oregius, Inchofer, and Pasqualigus, delivered their opinions on the case. Oregius declared that in the Dialogues the doctrine that the earth moves and that the sun is stationary is held and defended. Inchofer declared that Galileo not only taught and defended that doctrine, but was himself suspiciously inclined to it, and even held it to this day. Pasqualigus was of opinion that by the publication of his Dialogues Galileo had infringed the order of 1616 in respect to teaching and defending, and it was very suspicious that he held the prohibited doctrine.

On hearing of her father's imprisonment Maria Celeste wrote in deep distress, 20th April :—

"I have just been informed by Signor Bocchineri of your being imprisoned in the Holy Office. At this, though on the one hand it grieves me much, feeling sure that you are anxious and uneasy and, perhaps, without bodily comfort, yet on the other hand, considering that it must have come to this before the business could be terminated, and considering also the benignancy with which you have personally been treated, and (above all) the righteousness of your cause and your innocence in this particular matter, I feel comforted, and hope for a prosperous ending with the help of Almighty God, to Whom I cry without ceasing, recommending you to His care, with the greatest love and confidence. Only be of good cheer. Do not give way to grief,

for fear of the effect it would have on your health. Turn your thoughts to God, and put your trust in Him who like a loving Father never forsakes those who trust in Him unceasingly.

"My dearest Lord and father, I have written instantly on learning this news of you, that you might know how I sympathise with you in your distress. Perhaps, when you know this it will not be quite so hard to bear. I have mentioned the news to no creature in this house, choosing to make my joy and gladness common to all, but to keep my troubles to myself. Consequently, every one is looking forward joyfully to seeing you back again. And who knows? Perhaps, even while I am writing the crisis may be passed, and you may be relieved of all anxiety. May it be the Lord's will, in whose keeping I leave you."

Fearing that during Galileo's detention within the walls of the Holy Office, his letters to his daughter might be delayed if not detained, Caterina Niccolini (the Ambassador's wife) with sweet thoughtfulness wrote to Maria Celeste telling her what she knew of the situation, but still presenting the bright side (as Galileo himself had been doing) lest the poor nun should be too much distressed. It would appear from more than one of Maria Celeste's letters that the father had spoken so much to the Ambassadress about his daughter as to make her Excellency wish for a personal acquaintance, and she signified her intention of paying the Sister a visit on her return to Florence. From a letter written to her father some time later, we learn that Maria Celeste was expecting Signora Caterina with a mixture of pleasure and trepidation.

After the first hearing of his case on 12th April,

weeks passed and no further open step was taken in the trial; meanwhile, the prolonged deprivation of exercise in the open air which had been so essential to his health, combined with mental agitation, threw the old man on a sick bed. Writing on 23rd April to Geri Bocchineri he says:—

"I am writing in bed to which I have been confined for sixteen hours with severe pains in my loins, which according to my experience will last as much longer. A little while ago I had a visit from the Commissary and the Fiscal who conduct the enquiry. They have promised and intimated it as their settled intention to terminate the case as soon as I am able to get up again, encouraging me repeatedly to keep up my spirits. I place more confidence in these promises than in the hopes held out to me before, which as experience has shown were founded rather upon surmises than real knowledge. I have always hoped that my innocence and uprightness would be brought to light, and I now hope it more than ever.

"Please send this on to my daughters and Vincenzio, as usual."

The second examination was fixed for 28th April, and the course it now took had up to recent years puzzled all students of this famous trial. While at the close of his first examination we have seen Galileo deny having defended the Copernican doctrine, and assert that he had done just the opposite, now at this second hearing and almost without waiting for the Inquisitor's questions, he makes a declaration which, roundabout though it is, contains a penitent confession that he *had* defended those doctrines. The cause of this change is explained by a letter from one of

Galileo's judges, the Commissary - General Firenzuola (who was then with the Pope in the Castle of Gandolfo), to Cardinal Francesco Barberini, and dated 28th April.[1] This interesting letter (slightly condensed) runs as follows :—

"In compliance with the commands of his Holiness I yesterday informed the Congregation of the state of Galileo's case. Their Eminences approved of what has been done thus far, and took into consideration various difficulties with regard to the manner of pursuing the case, and of bringing it to an end. More especially as Galileo has in his examination denied what is plainly evident in his book; and in consequence of this denial there would result the necessity for greater rigour of procedure, and less regard to the other considerations belonging to the business. Finally, I suggested that the Congregation should grant me permission to treat extra-judicially with Galileo in order to render him sensible of his error, and bring him to a confession of the same; and upon my indicating the grounds upon which I made the suggestion, permission was granted me. That no time might be lost I entered into discourse with Galileo yesterday afternoon, and, after many arguments and rejoinders had passed between us, by God's grace I attained my object, for I brought him to a full sense of his error, so that he is willing to confess it judicially. He requested, however, a little time in order to consider the form in which he might most fittingly make the confession. I trust his Holiness and your Eminence will be satisfied that in this way the affair will be settled without difficulty; the Court will maintain its reputation; it will be possible to deal leniently with the culprit;

[1] First published in Pieralisi's "Urbano VIII. e Galileo : Memorie Storiche," Rome, 1875, pp. 197-8.

and, whatever the decision arrived at, he will recognise the favour shown him, with all the other consequences of satisfaction herein desired. To-day I think of examining him in order to obtain the said confession, and, having as I hope received it, it will only remain to me further to question him with regard to his intention, and to impose the prohibitions upon him; and that done he might have the house [Niccolini's] assigned as a prison, as hinted to me by your Eminence."

The second examination did not take place on 28th April as Firenzuola proposed, perhaps on account of Galileo's indisposition. On 30th April the Court again assembled, the usual oath to speak the truth was administered, and Galileo was requested to state what he had to say. He then began the following melancholy confession:—

"In the course of some days' continuous and attentive reflection on the interrogations put to me on the 12th of the present month, and in particular as to whether sixteen years ago an injunction was intimated to me by order of the Holy Office forbidding me to hold, defend, or teach, in any manner, the opinion that had just been condemned—of the motion of the earth and the stability of the sun—it occurred to me to reperuse my printed Dialogues (which for three years I had not seen), in order carefully to note whether, contrary to my most sincere intention, there had by any inadvertence fallen from my pen anything from which a reader or the authorities might infer not only some taint of disobedience on my part, but also other particulars which might induce the belief that I had contravened the orders of Holy Church. And being by the kind permission of the authorities at liberty to send about my servant, I succeeded in procuring

a copy of my book, and having procured it I applied myself with the utmost diligence to its perusal and to a most minute consideration thereof. And, owing to my not having seen it for so long, it presented itself to me as if it were a new writing and by another author. I freely confess that in several places it seemed to me set forth in such a form that a reader ignorant of my real purpose might have had reason to suppose that the arguments adduced on the false side, and which it was my intention to refute, were so expressed as to be calculated rather to compel conviction by their cogency than to be easy of refutation. Two arguments there are in particular—the one taken from the Sun-spots, the other from the ebb and flow of the tide—which in truth come to the ear of the reader with far greater show of force and power than ought to have been imparted to them by one who regarded them as inconclusive and who intended to refute them; as, indeed, I truly and sincerely held and do hold them to be inconclusive and admitting of refutation. And as excuse to myself for having fallen into an error so foreign to my intention, not contenting myself merely with saying that when a man recites the arguments of the opposite side with the object of refuting them, he should, especially if writing in the form of dialogue, state them in their strictest form, and should not cloak them to the disadvantage of his opponent. Not contenting myself with saying this, I now see I was misled by that natural complacency which every man feels with regard to his own subtleties and in showing himself more skilful than the generality of men in devising, even in favour of false propositions, ingenious and plausible arguments. However, although with Cicero *avidior sim gloriae quam satis est*, if I had now to set forth the same reasonings, without doubt I should

so weaken them that they should not be able to make an apparent show of force of which they are really and essentially devoid. My error then has been—and I confess it—one of vainglorious ambition and of pure ignorance and inadvertence.

"This is what occurs to me to say with reference to this particular, and what suggested itself to me during the reperusal of my book."

After making this humiliating declaration, Galileo was allowed to withdraw, and no questions were put to him; but he must have concluded from this silence or other sign that he had not gone far enough in the denial of his inmost convictions; perhaps, this penitent acknowledgment of error and vain-glory was not sufficient, and the Inquisitors would be conciliated by the resolution to publicly correct his error—whatever prompted the impulse he returned at once to the Court and spoke as follows:—

"And in confirmation of my assertion, that I have not held and do not hold as true the opinion which has been condemned, if there shall be granted to me, as I desire, means and time to make a clearer demonstration thereof, I am ready to do so; and there is a favourable opportunity for this, seeing that in the work the interlocutors agree to meet again after a certain time, to discuss several distinct problems of nature connected with the matter discussed at their meetings. As this affords me an opportunity of adding one or two other 'days,' I promise to take up the arguments already adduced in favour of the said opinion, which is false and has been condemned, and to confute them in such most effectual manner as by the blessing of God will be possible to me. I pray, therefore, this sacred

tribunal to aid me in this good resolution, and to enable me to put it into effect."

On the evening of the day on which the second hearing took place, 30th April 1633, Galileo was permitted to return to the Tuscan Embassy, on oath not to leave it, not to hold intercourse with any but the inmates of the house, to present himself before the Holy Office when summoned, and to maintain the strictest silence on the subject of the trial. At this wholly unexpected favour, Niccolini and his household were, as we may imagine, filled with delight, and not less, we may be sure, was the rejoicing at San Matteo, when Galileo's letter arrived with the good news. Replying on 7th May, Maria Celeste says:—

"The joy that your last dear letter brought me, and the having to read it over and over to the nuns, who made quite a jubilee on hearing its contents, put me into such an excited state, that at last I got a severe headache. I do not say this to reproach you, but to show how I take to heart all your concerns. And though I am not more strongly affected by what happens to you than a daughter ought to be, yet I dare to say that the love and reverence I bear my dearest Lord and father do surpass by a good deal that of the generality of daughters; and I know that in like manner he excels most parents in his love of me, his daughter. I give hearty thanks to our gracious God for the mercies you have hitherto received. You justly say all our mercies come from Him; and though you consider these now received as an answer to my prayers, yet truly they count for little or nothing. But God knows how dearly I love you, and so He hears me."

A week later, 14th May, she writes again:—

"You will have heard already what joy and comfort your last letter gave me. As I was obliged to give it to Signor Geri that Vincenzio might see it, I made a copy which Signor Rondinelli will take into Florence to read to some of his friends, who he knew would be extremely glad to hear the particulars."

After a long detailed account of her stewardship in the management of his property, she goes on:—

"I wonder at Vincenzio never having written to you, and I glory in having been beforehand with him in writing constantly, notwithstanding that I too have sometimes found time wanting. To-day, I have written this at four different times, having had constant interruptions from the pharmacy [of which she was keeper], and also from the toothache, which has been troublesome for many days past."

For once Maria Celeste seems to be unjust to her brother. Vincenzio did not write, it is true, but the reason was that fear of the plague had interrupted all communication between the healthy and the infected districts. He had not long before condescended to accept an appointment as clerk at Poppi, chief town of the Casentino, a district to which the scourge had not penetrated. Vincenzio does not appear to have held this appointment very long, for we learn that, owing to his inefficiency and carelessness, he was requested to send in his resignation, or suffer dismissal. Writing to Galileo on this subject, Bocchineri says:—

"I wish you would write and tell him to mind his business, and not waste his time over his new invention—a tuning-fork or some such thing—which might serve well enough to employ him after business hours, but which ought not to be the principal occupation of the day."

Poor Galileo!

On 10th May, Galileo was summoned for the third time before the Inquisition, where the Commissary-General, Firenzuola, informed him that eight days were allowed in which to prepare a defence if he wished to do so; but Galileo at once handed in a paper, from which we may conclude that it was written to order, and under the same extra-judicial pressure as made him write his humiliating confession of 30th April. The greater part of this document is taken up with an explanation why he had not mentioned the prohibition of 1616 when applying for the *Imprimatur* in 1630—which explanation amounts to a formal admission that on 26th February 1616 he was not only commanded not to hold or defend the Copernican doctrine, but not to teach it in any way whatsoever. Coming then to the last paragraph he says:—

"Lastly, it remains for me to pray you to take into consideration my pitiable state of bodily indisposition, to which at the age of seventy years, I have been reduced by ten months of constant mental anxiety, and the fatigue of a long and toilsome journey at the most inclement season, together with the loss of the greater part of the years of which, from my previous condition of health, I had the prospect. I am encouraged to

ask this indulgence by the clemency and goodness of the most eminent lords, my judges, and hope that they will be pleased to remit what may appear good to their entire justice, and to consider my sufferings as adequate punishment."

This touching appeal to the mercy of his judges cannot be read without feelings of the profoundest pity for the crushed old man, who in the evening of a glorious life was thus compelled to deny his inmost convictions, and to sue cravenly for that pity which was not to be shown him.

After his paper had been received, and the same obligations imposed on him on oath as after the second hearing, he was allowed to return to the Embassy. The nearer the time approached when his illusions were to be dispelled, the more sanguine was the intelligence he sent to his friends. A favour granted just at the last, on the urgent solicitation of Niccolini, and unheard of in the annals of the Inquisition, might have encouraged these confident hopes. He was permitted to take the air in the gardens of the Villa Medici on the Pincio, to which, however, he was always conveyed in a closed carriage, as he must not be seen in the streets! Niccolini did not share in these hopes of his guest. After an audience of the Pope and Cardinal Barberini, he wrote to Cioli (22nd May):—

"I very much fear that the book will be prohibited, unless it is averted by Galileo's being charged (as I suggested) to write an apology. Some salutary penance will also be imposed, as they maintain that he has transgressed the com-

mand given to him by Cardinal Bellarmine in 1616. I have not yet told Galileo all this, because I want to prepare him for it by degrees, in order not to distress him."

A lull now took place in the proceedings—the preparation for the great catastrophe that was to crush Galileo and fill the educated world with horror. Sultry silence reigned for four weeks, and no one, not even Niccolini, could learn anything. Indeed, the thunderbolt had fallen before the fact was known outside the Holy Office. Galileo's fate had been sealed at a private meeting of the Congregation, 16th June 1633, at which the Pope presided. It was decreed to try Galileo as to his intention, under threat of torture, and if this failed he was then to be called upon to recant before a plenary assembly of the Holy Office; to be condemned to imprisonment at their pleasure; and to be ordered in future not to discuss in writing or speaking the opinion that the earth moves and that the sun is stationary, nor even the contrary opinion, under pain of further punishment as a relapsed heretic. Further, the work "Dialogo di Galileo Galilei, Linceo," was to be prohibited.[1] And, in order to make this known everywhere, copies of the sentence were to be sent to all Papal envoys and to all Inquisitors into heretical crimes, and especially to the Inquisitor in Florence, who were to read it publicly to all professors of mathematics summoned for the purpose.

[1] From the Vatican MSS. it was apparently first intended to publicly burn the book, but after the decree was drafted, the words *Cremandum fore* were erased and *prohibendum fore* inserted.

Two days after these proceedings had been determined on, the Pope received Niccolini, who once more came to beg for a speedy termination of the trial, the long suspense of which was torturing to him only in a less degree than it was to Galileo himself. Urban coolly replied that it had already been terminated, and that within the next few days Galileo would be summoned to hear his sentence. The Ambassador, aghast at this unexpected answer, implored the Pope to mollify any severity that the judges might, perhaps, have thought necessary, and added that the great complaisance hitherto shown to his Sovereign's wishes in the matter was fully appreciated, and that the Grand Duke was only waiting the end of the business to express his gratitude in person. The Pope replied that his Highness need not take this trouble, that he had readily granted every amelioration possible; but as to Galileo's opinions they could do no less than prohibit them as erroneous and contrary to Holy Scripture, and as to his person, he would, according to usage, be imprisoned for a time, because he had transgressed the mandate issued to him in 1616. "However," added Urban, "after the publication of the sentence we will see you again and we will consult together so that he may suffer as little distress as possible."

The same day, 18th June, Niccolini reported this audience to Cioli, and remarked at the end that he had simply informed Galileo of the approaching end of the trial and of the prohibition of his book, but had said nothing about the

personal punishment, in order not to trouble him too much at once. The Pope had also enjoined this course, "because, perhaps, in the course of the proceedings things might take a better turn." The drama now rapidly proceeded to a climax. On the evening of 20th June 1633, Galileo was warned to appear before the Inquisition on the following morning, when, as we know from the programme of 16th June, he was to be questioned under threats of torture about his "intention" that is, as to his real convictions.

On the morning of the 21st, Galileo appeared before his judges. After he had taken the usual oath and had answered in the negative the query whether he had any statement to make, the examiner asked three separate questions, slightly varied but all to the effect whether he has held and holds the opinion that the sun is the centre of the world, and that the earth is not the centre, but moves, and with a diurnal motion. To these Galileo suitably replied in the negative. "I do not hold," he says, in reply to the last query, "and have not held this opinion of Copernicus since the command was given me that I must abandon it. For the rest I am here in your hands, do with me as you please." Being once more bidden to speak the truth, otherwise recourse would be had to torture, the terrified old man answered with the resignation of despair, "I am here to obey. I have not held this opinion since the decision was pronounced, as I have stated."

In the protocol of the trial the concluding

sentence follows immediately after Galileo's answer, "And as nothing further could then be done in execution of the decree [of 16th June] his signature was obtained to his depositions, and he was sent back to his place," that is, to some place in the buildings of the Holy Office, where he was detained till 24th June.[1]

We have no information as to the treatment he received this time. Was he put into the apartments he had occupied before, or was he confined in a prisoner's cell? From the considerate treatment in outward things which Galileo met with during his trial, we may, perhaps, conclude that he was not *thrown into the dungeons of the Inquisition* as so many historians are fond of repeating. Neither is there, as we shall presently see, the slightest foundation for another vulgar error—that he was actually put to the torture.

[1] Despatch, Niccolini to Cioli, 26th June 1633.

## CHAPTER XIV

### SENTENCE OF THE INQUISITION AND GALILEO'S ABJURATION—EXILED TO SIENA

### 1633

On Wednesday, 22nd June 1633, in the forenoon, Galileo was conducted to the large hall used for melancholy proceedings of this kind in the Dominican Convent of Santa Maria sopra Minerva, where in the presence of his judges and a large assemblage of cardinals and prelates of the Church his sentence was read to him as follows:[1]—

"We, the undersigned,

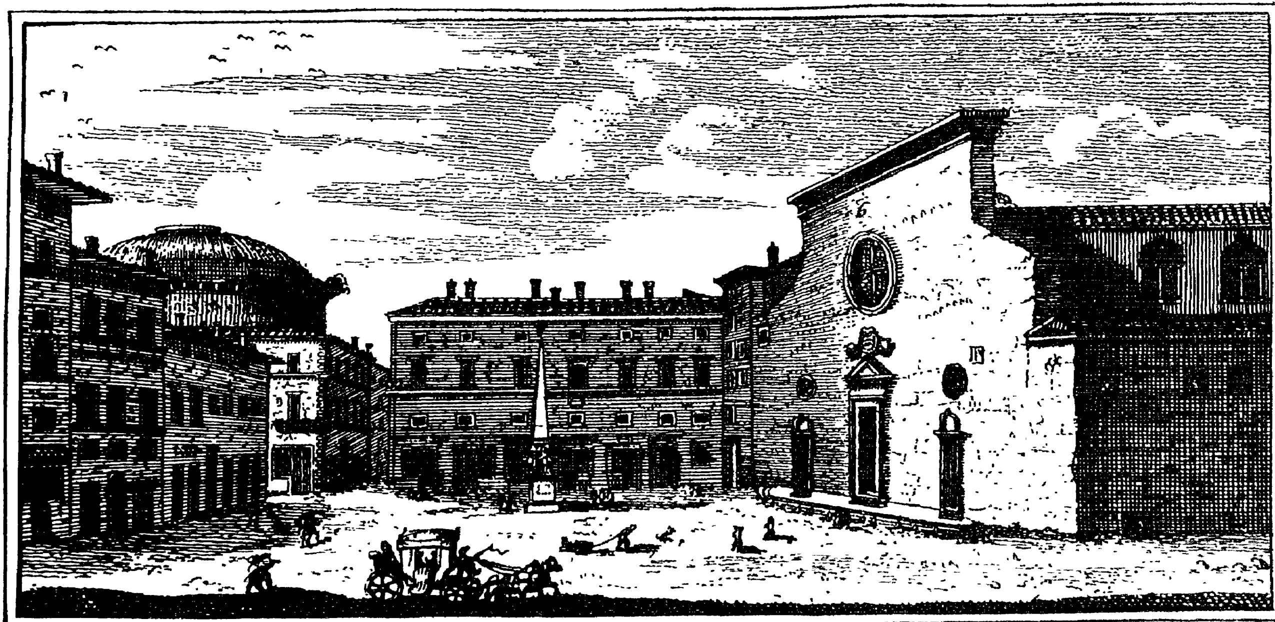
Gasparo of Santa Croce in Gerusalemme, Borgia,
Fra Felice Centino of S. Anastasia, called Ascoli,
Guido of Santa Maria del Popolo, Bentivoglio,
Fra Desiderio Scaglia of S. Carlo, called Cremona,
Fra Antonio Barberini, called S. Onofrio,[2]
Laudivio Zacchia of S. Pietro in Vincoli, called San-Sisto,
Berlingero of San Agostino, Gessi,
Fabrizio of S. Lorenzo in Pane e Perna, Verospi,
Francesco of S. Lorenzo in Damaso, Barberini,[3]
Martino of Santa Maria Nuova, Ginetti,

"by the grace of God, Cardinals of the Holy

[1] Jean-Jacques Bouchard writing from Rome to Micanzio, 29th June 1633, says "he was conducted as a criminal in penitential garb."

[2] Pope's brother.

[3] Pope's nephew.



PROSPECTVS AREÆ S. MARIÆ SVPRA MINERVAM

Santa Maria Sopra Minerva, Rome, *tempo* Galileo.

[*To face p.* 312.

Roman Church, Inquisitors General throughout the whole Christian Republic, Special Deputies of the Holy Apostolical Chair against heretical depravity:

"Whereas you, Galileo, son of the late Vincenzio Galilei, of Florence, aged 70 years, were denounced, in 1615, to this Holy Office, for holding as true a false doctrine taught by many, namely, that the sun is immovable in the centre of the world, and that the earth moves, and also with a diurnal motion; also, for having pupils whom you instructed in the same opinions; also, for maintaining a correspondence on the same with some German mathematicians; also for publishing certain letters on the sun-spots, in which you developed the same doctrine as true; also for answering the objections which were continually produced from the Holy Scriptures, by glozing the said Scriptures according to your own meaning; and whereas thereupon was produced the copy of a writing, in form of a letter, professedly written by you to a person formerly your pupil, in which, following the hypothesis of Copernicus, you include several propositions contrary to the true sense and authority of the Holy Scriptures; therefore (this Holy Tribunal being desirous of providing against the disorder and mischief which were thence proceeding and increasing to the detriment of the Holy Faith) by the desire of his Holiness and of the Most Eminent Lords, Cardinals of this supreme and universal Inquisition, the two propositions of the stability of the sun, and the motion of the earth, were qualified by the Theological Qualifiers as follows:

"1. The proposition that the sun is in the centre of the world and immovable from its place is absurd, philosophically false, and formally

heretical; because it is expressly contrary to the Holy Scriptures.

"2. The proposition that the earth is not the centre of the world, nor immovable, but that it moves, and also with a diurnal motion, is also absurd, philosophically false, and, theologically considered, at least erroneous in faith.

"But whereas, being pleased at that time to deal mildly with you, it was decreed in the Holy Congregation, held before his Holiness on the twenty-fifth day of February 1616, that his Eminence the Lord Cardinal Bellarmine should enjoin you to give up altogether the said false doctrine; and if you should refuse, that you should be ordered by the Commissary of the Holy Office to relinquish it, not to teach it to others, nor to defend it; and in default of acquiescence, that you should be imprisoned; and whereas in execution of this decree, on the following day, at the Palace, in presence of his Eminence the said Lord Cardinal Bellarmine, after you had been mildly admonished by the said Lord Cardinal, you were commanded by the Commissary of the Holy Office, before a notary and witnesses, to relinquish altogether the said false opinion, and, in future, neither to defend nor teach it in any manner, neither verbally nor in writing, and upon your promising obedience you were dismissed.

"And, in order that so pernicious a doctrine might be altogether rooted out, nor insinuate itself further to the heavy detriment of the Catholic truth, a decree emanated from the Holy Congregation of the Index prohibiting the books which treat of this doctrine, declaring it false, and altogether contrary to the Holy and Divine Scripture.

"And whereas a book has since appeared

published at Florence last year, the title of which showed that you were the author, which title is 'The Dialogue of Galileo Galilei, on the two principal Systems of the World—the Ptolemaic and Copernican'; and whereas the Holy Congregation has heard that, in consequence of printing the said book, the false opinion of the earth's motion and stability of the sun is daily gaining ground, the said book has been taken into careful consideration, and in it has been detected a glaring violation of the said order, which had been intimated to you; inasmuch as in this book you have defended the said opinion, already, and in your presence, condemned; although, in the same book, you labour with many circumlocutions to induce the belief that it is left by you undecided and merely probable; which is equally a very grave error, since an opinion can in no way be probable which has been already declared and finally determined contrary to the Divine Scripture. Therefore, by Our order, you have been cited to this Holy Office, where, on your examination upon oath, you have acknowledged the said book as written and printed by you. You also confessed that you began to write the said book ten or twelve years ago, after the order aforesaid had been given. Also, that you had demanded licence to publish it, without signifying to those who granted you this permission that you had been commanded not to hold, defend, or teach, the said doctrine in any manner. You also confessed that the style of the said book was, in many places, so composed that the reader might think the arguments adduced on the false side to be so worded as more effectually to compel conviction than to be easily refutable, alleging, in excuse, that you had thus run into an error, foreign

(as you say) to your intention, from writing in the form of a dialogue, and in consequence of the natural complacency which every one feels with regard to his own subtleties, and in showing himself more skilful than the generality of mankind in contriving, even in favour of false propositions, ingenious and plausible arguments.

"And, upon a convenient time being given you for making your defence, you produced a certificate in the handwriting of his Eminence the Lord Cardinal Bellarmine, procured, as you said, by yourself, that you might defend yourself against the calumnies of your enemies, who reported that you had abjured your opinions, and had been punished by the Holy Office; in which certificate it is declared that you had not abjured nor had been punished, but merely that the declaration made by his Holiness, and promulgated by the Holy Congregation of the Index, had been announced to you, which declares that the opinion of the motion of the earth and stability of the sun is contrary to the Holy Scriptures, and, therefore, cannot be held or defended. Wherefore, since no mention is there made of two articles of the order, to wit, the order 'not to teach' and 'in any manner,' you argued that we ought to believe that, in the lapse of fourteen or sixteen years, they had escaped your memory, and that this was also the reason why you were silent as to the order when you sought permission to publish your book, and that this is said by you, not to excuse your error, but that it may be attributed to vain-glorious ambition rather than to malice. But this very certificate, produced on your behalf, has greatly aggravated your offence, since it is therein declared that the said opinion is contrary to the Holy Scriptures, and yet you have dared to treat of it, and to argue

that it is probable. Nor is there any extenuation in the licence artfully and cunningly extorted by you, since you did not intimate the command imposed upon you. But whereas it appeared to Us that you had not disclosed the whole truth with regard to your intention, We thought it necessary to proceed to the rigorous examination of you, in which (without any prejudice to what you had confessed, and which is above detailed against you, with regard to your said intention) you answered like a good Catholic.[1]

"Therefore, having seen and maturely considered the merits of your cause, with your said confessions and excuses, and everything else which ought to be seen and considered, We have come to the underwritten final sentence against you:

"Invoking, therefore, the most holy name of our Lord Jesus Christ, and of His Most Glorious Virgin Mother, Mary, We pronounce this Our final sentence, which, sitting in council and judgment with the Reverend Masters of Sacred Theology and Doctors of both Laws, Our Assessors, We put forth in this writing in regard to the matters and controversies between the Magnificent Carlo Sincero, Doctor of both Laws, Fiscal Proctor of the Holy Office, of the one part, and you, Galileo Galilei, defendant, tried and confessed as above, of the other part, We pronounce, judge, and declare, that you, the said Galileo, by reason of these things which have been detailed in the course of this writing, and which, as above, you have confessed, have rendered yourself vehemently suspected by this Holy Office of heresy, that is of having believed and held the doctrine (which is false and contrary to the Holy and Divine

[1] The phrase is vague and purposely so, for clearly, even the threat of torture could not extort from Galileo the wished-for avowal of his "intention," that is of his still holding the condemned opinion. See Martin's "Galilée," pp. 129-31.

Scriptures), that the sun is the centre of the world, and that it does not move from east to west, and that the earth does move, and is not the centre of the world; also, that an opinion can be held and supported as probable, after it has been declared and finally decreed contrary to the Holy Scripture, and, consequently, that you have incurred all the censures and penalties enjoined and promulgated in the sacred canons and other general and particular constitutions against delinquents of this description. From which it is Our pleasure that you be absolved, provided that with a sincere heart and unfeigned faith, in Our presence, you abjure, curse, and detest, the said errors and heresies, and every other error and heresy, contrary to the Catholic and Apostolic Church of Rome, in the form now shown to you.

"But that your grievous and pernicious error and transgression may not go altogether unpunished, and that you may be made more cautious in future, and may be a warning to others to abstain from delinquencies of this sort, We decree that the book 'Dialogues of Galileo Galilei' be prohibited by a public edict, and We condemn you to the formal prison of this Holy Office for a period determinable at Our pleasure; and by way of salutary penance, We order you during the next three years to recite, once a week, the seven penitential psalms, reserving to Ourselves the power of moderating, commuting, or taking off, the whole or part of the said punishment or penance.[1]

[1] Accordingly, the work was placed on the Index Expurgatorius, and for more than a hundred years after, it was not allowed to be printed in Italy, and then (1744) the editor had to state expressly in an introduction that the theory of the double motion of the earth must be regarded only as a mathematical hypothesis to facilitate the explanation of certain natural phenomena. He had also to prefix the sentence of the Holy Office and Galileo's recantation, as well as

"And so We say, pronounce, and by Our sentence declare, decree, and reserve, in this and in every other better form and manner, which lawfully We may and can use. So We, the subscribing Cardinals, pronounce.

"FELIX, Cardinal di Ascoli.
"GUIDO, Cardinal Bentivoglio.
"DESIDERIO, Cardinal di Cremona.
"ANTONIO, Cardinal S. Onofrio.
"BERLINGERO, Cardinal Gessi.
"FABRIZIO, Cardinal Verospi.
"MARTINO, Cardinal Ginetti."

In conformity with the foregoing sentence, Galileo was made to kneel before the Inquisition, and make the following abjuration:—

"I, Galileo Galilei, son of the late Vincenzio Galilei of Florence, aged seventy years, being brought personally to judgment, and kneeling before you, Most Eminent and Most Reverend Lords Cardinals, General Inquisitors of the Universal Christian Republic against heretical depravity, having before my eyes the Holy Gospels which I touch with my own hands, swear that I have always believed, and, with the help of God, will in future believe, every article which the Holy Catholic and Apostolic Church of Rome holds, teaches, and preaches. But because I have been

Calmet's essay "On the System of the Universe of the Ancient Hebrews," in which the passages of Scripture relating to the order of the world are supposed to be interpreted in true Catholic fashion. But see p. 427 *infra*.

After many attempts in the next eighty years to have the decree of 5th March 1616 (prohibiting all books which teach the Copernican doctrine) expunged, it was finally resolved, 11th September 1822, "that the printing and publication of works treating of the motion of the earth and the stability of the sun, in accordance with the opinion of modern astronomers, is permitted in Rome." Accordingly, in the next edition of the Index, published in 1835, Galileo's name, Kepler's, and those mentioned in the decree of 5th March 1616, were expunged.

enjoined, by this Holy Office, altogether to abandon the false opinion which maintains that the sun is the centre and immovable, and forbidden to hold, defend, or teach, the said false doctrine in any manner; and because, after it had been signified to me that the said doctrine is repugnant to the Holy Scripture, I have written and printed a book, in which I treat of the same condemned doctrine, and adduce reasons with great force in support of the same, without giving any solution, and therefor have been judged grievously suspected of heresy; that is to say, that I held and believed that the sun is the centre of the world and immovable, and that the earth is not the centre and movable, I am willing to remove from the minds of your Eminences, and of every Catholic Christian, this vehement suspicion rightly entertained towards me, therefore, with a sincere heart and unfeigned faith, I abjure, curse, and detest the said errors and heresies, and generally every other error and sect contrary to the said Holy Church; and I swear that I will never more in future say, or assert anything, verbally or in writing, which may give rise to a similar suspicion of me; but that if I shall know any heretic, or any one suspected of heresy, I will denounce him to this Holy Office, or to the Inquisitor and Ordinary of the place in which I may be. I swear, moreover, and promise that I will fulfil and observe fully all the penances which have been or shall be laid on me by this Holy Office. But if it shall happen that I violate any of my said promises, oaths, and protestations (which God avert!), I subject myself to all the pains and punishments which have been decreed and promulgated by the sacred canons and other general and particular constitutions against delinquents of this description. So, may God help me, and His Holy Gospels, which I touch with my own hands, I, the above

named Galileo Galilei, have abjured, sworn, promised, and bound myself as above; and, in witness thereof, with my own hand have subscribed this present writing of my abjuration, which I have recited word for word.

"At Rome, in the Convent of Minerva, 22nd June 1633, I, Galileo Galilei, have abjured as above with my own hand." [1]

A notable circumstance connected with these papers is that, whereas the names of ten Cardinals appear in the preamble of the sentence, only seven subscribed it. The three who did not sign deserve to be specifically mentioned; they were Gasparo Borgia, Laudivio Zacchia, and Francesco Barberini, the Pope's nephew. Why did these Cardinals abstain from signing? Were they absent accidentally, or on purpose? Or did they dissent and refuse to sign? We shall probably never know; but bearing in mind the many instances of Francesco Barberini's good offices in Galileo's behalf, we shall not be far wrong, I think, if we conclude that they did not sign because they did not approve the sentence. Another of the ten, Cardinal Bentivoglio,

[1] The Vatican MSS. relating to Galileo's trial have a curious history of their own. They were carried away in 1809 by order of Napoleon to Paris, where they remained until his first abdication. Just before the Hundred Days, the King, Louis XVIII., wishing to inspect them, ordered them to be sent to his private apartments. In the hasty flight which soon afterwards followed, the MSS. were forgotten, and disappeared in an unaccountable way. After some years they were restored to Pope Gregory XVI., in an equally mysterious manner, and were finally replaced in the Vatican Library by Pope Pius IX., in 1848. A French translation, begun by Napoleon's orders, was brought down to 30th April 1633, when, no doubt, the Emperor's abdication prevented its completion. For more on this subject, see Favaro's "Documenti del Processo di Galileo," Venice, 1902.

although he signed, is said to have done his best to prevent the decision arrived at; which is likely enough, seeing that he studied under Galileo in Padua, and was always reckoned as one of his disciples.[1] We may, then, suppose that at least four of the ten judges were against the sentence, which, if true, is another indication of the determination of Urban VIII. to punish his quondam friend for calling him a simpleton.[2]

It is also noteworthy that not one of the decrees or orders relating to this trial is ratified by the Pope. They all begin with the words *Sanctissimus mandavit*, but bear no Papal signature. This is equally the case in the proceedings of 1616 as in those of 1633. This fact is made much of by apologists of the Church of Rome. They argue that from the absence of the Pope's signature the Church cannot be held responsible. Galileo, they

[1] See his "Memorie," Venice, 1648, p. 123; also p. 288 *ante*, where Galileo says that Cardinals Bentivoglio and Scaglia were well disposed towards him. The Pope told Niccolini on 18th June that the Cardinals were unanimous "in intending to impose a penance." But were they unanimous in all other matters? It is well to note (as Professor Favaro points out) that his Holiness was not always sincere in his communications to Niccolini.

[2] Since the above was written, I have received a letter from Professor Favaro in which he says:—"The omission of the signatures has not the significance hitherto ascribed to it. The three Cardinals were not present, but there can be little doubt that, notwithstanding their good disposition towards Galileo personally (a feeling which was shared by others on the bench), they were assenting parties. Cardinal Borgia was at the time Spanish Ambassador to Rome, his relations with the Pope and the Barberini faction were strained, and he seldom if ever attended the sittings of the Holy Office. Cardinal Barberini, as we learn from one of Niccolini's despatches, never attended the *Wednesday* sittings. Cardinal Zacchia's absence was probably accidental, perhaps on account of ill-health."

say, was persecuted, not by the Pope, Urban VIII., the infallible vicar of Christ, but by the man, Maffeo Barberini, and his tools the Cardinals. Granted: but suppose a man be persecuted by the police in the name of, and to the knowledge of, the higher powers, are these higher powers to get off scot-free, because they did not put their hand and seal to the documents authorising the acts of their subordinates? However, since the apologists admit the persecution, we leave them to derive what comfort they can from their casuistical argument.[1]

For a long time it was a popular error that Galileo was subjected to torture.[2] The assertion is based on the mention in the sentence of a rigorous examination under which Galileo answered as became a good Catholic; and in support it is pointed out that after this time he was afflicted (in addition to his other maladies) with hernia, which was said to be the usual consequence of "torture by the cord." Now, as regards the latter it is enough to say that hernia was an old complaint, and is certified to by the Florentine physicians in their certificate of 17th December 1632, already quoted in these pages. As regards the rigorous examination, all histories of the Inquisition show that this formula consisted of five stages which had to be strictly followed: (1) threat in Court that extreme measures would be resorted to; (2) taking the

[1] For an excellent review, showing the injustice and illegality of these proceedings, see Von Gebler's "Galileo and the Roman Curia," pp. 234-42, or Martin's "Galilée,' chap. vii., where the whole affair is exhaustively discussed from a different standpoint.

[2] The fable is not dead yet, even amongst educated people. The latest repetition of it occurs in an article in the *Fortnightly Review* for March 1902.

accused into the torture chamber, renewing the threat, and showing him the instruments of torture; (3) undressing and binding; (4) laying him on the rack; and (5) actual torture (*territio realis*). Now, a close study of the proceedings clearly shows that it was not necessary to go beyond the first stage, for the compliance of the accused saved his judges from the ineffable disgrace of the crowning infamy. The difference to a man of Galileo's genius, years, and infirmities, was little if anything. The whole period of the trial, from his first citation to Rome on 1st October 1632 to the closing scene on 22nd June 1633, was one continued infliction of moral torture. The repeated denials of his inmost convictions, and the final abjuration on bended knees, must have wrung his soul as severely as physical torture could have wrung the muscles and tendons of his body.

Another error which early biographers were fond of repeating, but of which a moment's reflection would have shown the absurdity, was that Galileo on rising from his knees after reciting the abjuration muttered *Eppur si muove* (it moves, nevertheless). Some writers, doubtless to make the story more *vraisemblable*, provide a friend to whom the words are whispered. But consider for a moment the situation: an old man of seventy years, suffering in body, and distressed in mind by the accumulated anguish of a ten months' trial, alone and without support in the midst of that stern assembly of Inquisitors. Is it likely that at such a moment he would have muttered or uttered these words? He must have known that the slightest

indication by words or gesture of such a state of mind would have consigned him for life to the deepest dungeons of the Inquisition, if to no worse.[1]

While the older writers go to one extreme and say that Galileo was tortured, thrown into a dungeon for years, or for the rest of his life, was in physical fact a martyr, some recent ones go to the other extreme, and say he had no claim to much sympathy, brought his troubles on himself by want of tact and temper, was, in fact, as little of a martyr as it was possible to be. Others, again, blame him for not "seeing this thing through." Brewster, for example, compares him to the Christian martyr, and finds him sadly degenerate. "Had Galileo," he says, "but added the courage of the martyr to the wisdom of the sage; had he carried the glance of his indignant eye round the circle of his judges; had he lifted his hands to Heaven, and called on the living God to witness the truth and immutability of his opinions, the bigotry of his enemies would have been disarmed, and science would have enjoyed a memorable triumph." Perhaps; but perhaps on the other hand, his judges, instead of being cowed by the glance of his eye, would have delivered him to the stake, as they did Giordano Bruno earlier in the century (1600), and Marc' Antonio de Dominis only eight years before.[2] Revealed truth may require its martyrs, at least so Tertullian tells us—the blood

[1] The earliest mention of "Eppur si muove" occurs in "Querelles Littéraires," by L'Abbé Irailh, Paris, 1761, vol. iii. p. 49.

[2] De Dominis died in prison (1624) in the course of his trial, but his body was burned with his books by sentence of the Inquisition—*pour encourager les autres*, I suppose.

of the martyrs is the seed of the Church; but scientific truth certainly requires none, *pace* Brewster, for, as the Koran (strange authority) teaches, "the ink of the scholar and the blood of the martyr are of equal value in the eye of Heaven." Much as Galileo did for science, he would probably have done more were his life less stormy. From his entry into public life in 1589 to his death in 1642, he was seldom free from polemics. For over fifty years he was the knight militant of science, and almost alone did successful battle with the hosts of Churchmen and Aristotelians who attacked him on all sides—one man against a world of bigotry and ignorance. If, then, once and only once, when face to face with the terrors of the Inquisition, he, like Peter, denied his Master, no honest man, knowing all the circumstances, will be in a hurry to blame him.

After this sorrowful drama had been concluded, Galileo was led back to the buildings of the Holy Office. And now that he and the Copernican system had been condemned with all the terrifying forms of the Inquisition, Urban's wounded vanity was soothed, and he was pleased to give the word for a little mercy. Galileo was not, as the sentence prescribed, to be detained in the prison of the Holy Office, but was banished to the villa of the Grand Duke of Tuscany at Trinità dei Monti, which, by Papal orders dated 23rd June, he was to consider as a prison. Thither, where, many years before, he had shown the moons of Jupiter and other "Celestial Novelties" to wondering cardinals, he was now conducted by the

ever-faithful Niccolini on the evening of 24th June.

From Niccolini's letter to Cioli of 26th June we learn that while Galileo took the prohibition of his book (for which his friend had prepared him) with tolerable composure, the wholly unexpected proceedings against himself personally affected him terribly. He sank into a deep depression from which the Ambassador did his best to rouse him, but with little success for a time.

In accordance with the decree of 16th June 1633, copies of the sentence and abjuration were despatched to all Papal Nuncios, all Inquisitors, and many Universities, Italian and Foreign. In Padua and Florence especially, the means of publication were calculated with a refinement of cruelty. In Padua the local Inquisitor read both documents to the professors of philosophy and mathematics, and to the students convened for the purpose in the University library. A search was made for copies of the condemned book, and if none were found the Inquisitor could at least boast of one voluntary surrender. The peripatetic Fortunio Liceti gave up his copy—a presentation one by the author! In Florence the Inquisitor read the sentence and abjuration publicly in the church of Santa Croce, notices to attend having been previously served on all professors, and on all others who were known to be friends and adherents of Galileo. Thus Aggiunti, Guiducci, Arrighetti, and many others who loved the great master were made to participate in his humiliation.[1]

[1] See Guiducci's letter to Galileo, dated 27th August 1633.

But the cup of Papal wrath was not emptied on Galileo's head alone. All who had befriended him, or had any part in the licensing of his Dialogues, were punished in some way. Ciampoli, in December 1632, was deprived of his office of Secretary of the Papal Briefs and was (practically) exiled as Governor of Montalto, where he remained as long as he lived—Galileo's faithful disciple to the last. Early in April 1633 Galileo was deprived of the valuable advocacy of the devoted Castelli, who was sent away on some pretext, and was not recalled until the middle of 1635, when "At last he had again been permitted to kiss his Holiness's toe." The Inquisitor in Florence was severely reprimanded, and Riccardi, the Censor, was dismissed in disgrace and deprived of all offices during Urban's lifetime.

The inconsistency of these proceedings will be noted in the latter cases. These people are punished for granting that very licence which Galileo was charged with, and condemned for, having surreptitiously obtained from them by concealing circumstances with which they were not bound to be acquainted. Riccardi, in exculpation of his conduct, produced a letter from Ciampoli, in which it was said that his Holiness (in whose presence the letter professed to be written) ordered the licence to be given; but the Pope only replied that this was a Ciampolism; that his Secretary and Galileo had circumvented him; that he had already dismissed Ciampoli, and that Riccardi must prepare to follow him.

On the news of Galileo's condemnation reaching

his daughter, Maria Celeste wrote (on 2nd July):—

"The news of your fresh trouble has pierced my soul with grief—all the more that it came upon me quite unexpectedly. Not having had a letter from you this week, I feared something must have happened, and importuned Signor Geri to tell me. What I hear from him of the resolution they have taken concerning you and your book gives me extremest pain, not having expected such a result. Dearest Lord and father, now is the time for the exercise of that wisdom with which God has endowed you. Thus, you will bear these blows with that fortitude of soul which religion, your age, and your profession, alike demand."

Receiving no news direct from Galileo for some days after the promulgation of the sentence in Florence, Geri Bocchineri and Niccolò Aggiunti, fearing a descent on the villa at Arcetri by the familiars of the Inquisition, requested the keys of the house from Maria Celeste that they might do what Galileo had told them might be necessary to his safety should certain contingencies arise. Writing on 13th July, she tells her father:—

"They feared you were in trouble, and seeing how exceedingly anxious they were on your account, it seemed to me right and necessary to prevent any accident, therefore I gave them the keys and permission to do as they thought fit."

The author of the "Private Life of Galileo" thinks the work here hinted at was the burning of such writings in Galileo's library as might be used to further incriminate him.

"It is probable," the author says, "that much which was precious was destroyed on this occasion; and this may fully account for the disappearance of those incompleted writings of which mention is made in his correspondence, but of which no trace remains" (p. 263).

It is highly probable that as a matter of precaution Galileo's friends took away for safe hiding certain of his papers; but that anything was actually destroyed I doubt. With the exception of those early treatises (some of which may never have been written), noted on p. 120, no important paper of his is missing, and there is no perceptible break in his correspondence, except that already noted for the year of his third visit to Rome in 1616.[1]

Galileo, after his first great anguish had somewhat subsided, felt that he must quit Rome and its hateful memories, and so addressed a pitiable letter to the Pope.

"Most Holy Father," he says, "Galileo Galilei humbly begs your Holiness to exchange the place assigned to him for his prison near Rome for some other in Florence, which may appear suitable to your Holiness, in consideration of his poor health, and also because he is expecting a sister [in law] with eight children from Germany, to whom no one can afford help and protection so well as himself.[2] He will receive any disposition of your Holiness as a great favour."

But at the Vatican it was thought that to allow Galileo to return at once to Florence

[1] See p. 156 *ante*, and the Bibliography at end.
[2] A pretext, see "Galileo e Suor Maria Celeste," p. 188.

would be a superfluity of indulgence. "We must proceed gently," said his Holiness, "and only rehabilitate him by degrees." Still Urban was moved to some compassion, and on 30th June allowed the poor old man to retire to Siena, to the house of his former pupil Archbishop Ascanio Piccolomini, where he was to remain under the orders of the Archbishop, and on no account to leave the town without permission from Rome. Galileo was informed of this decision on 2nd July, and early on the 6th he shook the dust of Rome from off his feet. Niccolini, reporting his departure to Cioli (on 10th July), says: "Signor Galileo set out early on Wednesday in good health for Siena, and writes to me from Viterbo that he had performed four miles on foot, the weather being very cool."

Galileo reached Siena safely on 9th July, and was warmly received by Piccolomini; but neither his devoted kindness, not the stimulating converse with an old friend, the learned Alessandro Marsili, then residing at Siena, could make him forget that he was a prisoner of the Inquisition.

On 23rd July 1633, he wrote to Cioli:—

"To-day I address myself to you, oppressed by the *ennui* of a captivity of more than six months—a captivity made more painful by the chagrin and the anxiety of the preceding year, and by all the dangers and all the bodily sufferings which have followed in their train. My misfortunes are commiserated by all the world, except by those who have judged me deserving of this punishment—but of this another time.

"The duration of my captivity is entirely at

the pleasure of his Holiness. On the intervention of the Ambassador Niccolini, the Pope assigned me, instead of the prison of the Holy Office, the Villa de Medici, Trinità dei Monti, where I remained some days. Again, on the Ambassador's intercession, I was sent to the Archiepiscopal Palace here, where for fifteen days I have experienced the greatest kindness from the excellent Archbishop. But, apart from the wish that I have to return to my home and to be at liberty, this liberty is really essential to me. Therefore, I beg you to move his Highness to solicit the favour of my liberty from his Holiness, or through Cardinal Barberini. You might point out that the house of the Grand Duke has been for a long time deprived of my services, and insist on attaching to this circumstance more importance than it merits."

After all his bitter disillusions we see that his hopefulness had not yet abandoned him. The Grand Duke very kindly consented to exert once more what influence he possessed with the Pope, and instructed his ambassador accordingly; but Niccolini represented that the moment was not opportune, and recommended that action should be deferred for a few months. Meanwhile the good Archbishop did all that love for his venerated guest could suggest to make his house as little like a prison as possible, rather "an earthly paradise," as Maria Celeste wished her father to consider it; but for a long time these efforts had little effect. The cruel edict condemning him to perpetual silence on a subject which was one of the mainsprings of his life was a serpent's sting which could not be readily forgotten; his

soul was lacerated, and he fell into frequent fits of utter despondency, in which he accused his friends of having forgotten him. In one of these moments of bitterness he wrote to his daughter—"my name is erased from the book of the living." "Nay," came Maria Celeste's soothing reply, "say not that your name is struck out *de libro viventium*, for it is not so, neither in the greater part of the world, nor in your own country. Indeed, it seems to me that if for a brief moment your name and fame were clouded they are now restored to greater brightness; at saying which I am much astonished with myself, for I know that generally *nemo propheta acceptus in patria sua*. I am afraid that if I go on quoting Latin I shall fall into some barbarism, so I shall stop. But, indeed, you are loved and esteemed here more than ever."

As the weary months rolled on, Galileo became a little resigned to his situation at Siena, and even began to occupy himself with another of his great works (indeed the greatest), namely "Dialoghi delle Nuove Scienze" (or, Dialogues on The New Sciences), the writing of which he spoke of as far back as 1610, in his letter to Vinta. His interest in other scientific matters was as keen as ever. Thus, writing (27th September) to Andrea Arrighetti, a young Florentine disciple who had sent him some mathematical problems, he says:—

"The pleasure with which I read and re-read your demonstrations was greater than my astonishment, since the pleasure was proportionate to the sagacity of which you give proof in your

argumentation, while the astonishment was little, because I remembered I had under my eyes a work of Signor Andrea Arrighetti.

"The last theorem held me for a moment in meditation and in doubt, as much owing to the unusual formula as to fatigue of memory, which lets escape impressions as soon as formed. Let this be a lesson to you, and encourage you to exercise the mind while you are young.

"As regards myself, I can say that my relations with my kind and honoured host bring me much consolation, and in the midst of so many sad subjects for meditation they give a new direction to my thoughts. But more than any other consolation, the knowledge that you and my other friends retain for me your old affection makes my grief less heavy."

Galileo's detention at Siena would, perhaps, have been borne more easily did he not know that his loved and loving daughter, in spite of her resignation, was consuming her poor heart with longing to see him once more. "When you were in Rome I said to myself, if he were but at Siena! Now you are at Siena, I say, would he were at Arcetri! But God's will be done!" Her life was one continual prayer for him. Yet, while ever thinking of his spiritual welfare, she did not neglect his worldly affairs. In her letters of this period she tells him of the fruit and the wine which have been sold; of the incoming and outgoing of his money; that the vines had been injured by hail; that thieves had been over the garden wall; that his mule was behaving badly and would carry no one now her master was away; that a storm had damaged the roof, and thrown down and smashed a large vase;

that the plums were few; and that the wind had carried away the pears; and so on. With the money from the sale of some lemons she had had three masses said for her father's special benefit. Finally: "there are two pigeons," she says, "in the dovecot waiting for you to come and eat them; there are beans in the garden waiting for you to gather them; and your tower is lamenting your long absence."

As soon as the quarantine regulations were relaxed, Maria Celeste sent the boy Geppo on the mule to Siena to bring back news of her father, how he was looking, etc. The poor old man seems to have asked her to remember him in her prayers, for on Geppo's return she wrote (3rd October):—

"It seems to me a thousand years till I see you back again safe and well. I would not have you doubt that all this time I have never ceased from commending you to God with my whole heart, for, indeed, I feel too anxious for your spiritual and bodily health ever to have neglected praying for you. To give you a proof I will tell you that as a great favour I had a copy of your sentence shown to me, and though on the one hand it grieved me to read it, yet on the other hand I was glad, because I found out a way of being of some slight use to you, namely, by taking on myself that part of the sentence which orders you to recite the seven Penitential Psalms once a week. I began to do this a while ago, and it gives me much pleasure—first, because I am persuaded that prayer in obedience to Holy Church must be efficacious; secondly, in order to save you the trouble of remembering it. If I had been able to do more, most willingly would I have entered a straiter

prison than the one I live in now, if by so doing I could set you at liberty."

At length, the weariness and sickness of heart caused by hope deferred began to tell on this sweet nun. Worn by continual ill-health, by anxiety for her father, by nightly watchings in the convent infirmary, and daily occupations in the stillroom and pharmacy, she would appear to have felt a presentiment of her approaching dissolution. She strove gently to prepare her father, telling him it was for him to live long to the service and the glory of the God who had endowed him with such a wondrous intellect, and to the comfort of many who would feel his loss. As for herself, she could neither do much for the glory of God, nor be of much use to any one, and her living or dying would make little difference.

In November 1633, thinking the time favourable, Niccolini began to agitate for Galileo's pardon, but the Pope was not disposed to go so far, and pretended there would be a difficulty in getting the Congregation of the Holy Office to consent to such a course—a patent evasion, as the decision rested solely and entirely with himself. Niccolini, however, persisted in his efforts, and went to Cardinal Barberini and other members of the Congregation to enlist their good offices. At length, on 1st December, the question of Galileo's pardon, or rather release from personal restraints, came before the Congregation—the Pope presiding—and, though recommended by Cardinal Barberini, it was refused; but Galileo was per-

mitted to retire to his villa at Arcetri, where he was to remain till further orders, and where he might receive his friends and relations, but not too many at a time, if he wished to avoid suspicion.

While Niccolini's letter of 3rd December, containing this piece of good news, was on its way to Siena, Galileo was writing thus to Bocchineri in Florence (9th December):—

"For the last four days I have suffered from violent pains in the limbs which are more persistent than ordinary. I fear greatly that this climate (much more rigorous in winter than that of Florence) is the principal cause of these ailments; and I foresee that I shall be very seriously crippled if obliged to remain here much longer. I await a decision from Rome, but I have little hope of its being favourable."

For once Galileo despaired, and at the wrong moment! The same day Niccolini's letter of 3rd December arrived, and a few days afterwards he set out for Arcetri.

# CHAPTER XV

## GALILEO AT ARCETRI: COMPLETES HIS DIALOGUES ON THE TWO NEW SCIENCES

### 1634-1636

On returning to his villa, Il Giojello, after nearly a year's absence, Galileo's first care was to visit his daughters in the neighbouring convent of San Matteo; and afterwards, and when permitted to do so by the local Inquisitor, this was his greatest pleasure. But alas! this man of sorrows was soon to taste again the cup of affliction. When Maria Celeste heard that her father's prison had been changed to Arcetri, and that he may be expected in a few days, she hardly had strength enough to be glad.

"I do not think," she wrote on 3rd December, "that I shall live to see that hour. Yet may God grant it if it be for the best."

Her prayer was granted and hardly more. Before she lay down, weary and prematurely old, in her narrow bed in the little convent chapel, she was able to embrace her dearest Lord and father. What passed between those two sorely-tried and loving souls in the last few and suffering

weeks of the daughter's life it would be profanity to attempt to describe, even if we knew.

Sister Maria Celeste died on 2nd April 1634, in her 34th year, having been born on 13th August 1600. The rest that we know of her will best be given in the words of her heart-broken father. Writing to his friend, Elia Diodati, Paris, on 25th July 1634, he says:—

"I hope that when you hear of my past and present misfortunes, and my anxiety about those perhaps still to come, it will serve as an excuse to you and my other friends and patrons in Paris; to you for my long delay in answering your letter, and to them for my entire silence. According to the sentence pronounced on me by the Holy Office, I was condemned to imprisonment during the pleasure of his Holiness, who was pleased, however, to assign the palace and gardens of the Grand Duke near the Trinità dei Monti as my place of imprisonment. As this was in June of last year, and I had been given to understand that if I asked for a full pardon after the lapse of that and the following month I should receive it, I asked, meanwhile, to avoid having to spend the whole summer and, perhaps, part of the autumn there, to be allowed, on account of the climate, to go to Siena, where the Archbishop's house was assigned to me as a residence. I stayed there five months, when this durance was exchanged for banishment to this little villa, a mile from Florence, with a strict injunction not to go to the city, and neither to receive the visits of many friends at once, nor to invite any.

"Here, then, I was living, keeping perfectly quiet, and paying frequent visits to a neighbouring convent where two daughters of mine were living as

nuns. I was very fond of them, especially of the elder who possessed extraordinary mental gifts, combined with rare goodness of heart; and she was very much attached to me. During my absence, which she considered very perilous for me, she fell into a profound melancholy which undermined her health, and she was at last attacked by a violent dysentery of which she died after six days' illness, just thirty-three years of age, leaving me in the deepest grief."

Galileo was so overwhelmed by her death that it seemed to him as if he were destined speedily to follow her. "I hear her constantly calling me," he wrote to Geri Bocchineri on 27th April. In the rest of this letter we have a sad picture of the old man's desolation. From some alarming bodily symptoms, and his daughter's call resounding in his ears, he believed himself to be dying.

"I am going to write to you," he says, "about my health which is very bad. I suffer much more from the rupture than has been the case before. My pulse intermits, and I have often violent palpitation of the heart. Then, the most profound melancholy has come over me; I have no appetite and loathe myself; in short I feel myself perpetually called by my beloved daughter.

"Under these circumstances I do not think it advisable that Vincenzio should set out on a journey now; as events might occur at any time which might make his presence desirable; for, besides what I have mentioned, continued sleeplessness alarms me not a little. I tell you this that you may tell him if you think fit—not because I wish to disturb his plans, but because it seems to me that he ought to know. You, who can speak more firmly to him than I can, will say enough to make

him take the course which is most advisable. He has been asking for his allowance, 25 crowns; I enclose it to you to forward to him, as I do not want to say a single word, for him to turn and twist at his pleasure."[1]

As we see from the letter just quoted, Galileo was at this time suffering much from one of his many complaints (hernia). On its recurrence earlier in the year, he sought permission through the Tuscan Ambassador to move into Florence for the sake of the regular medical treatment which his case required, and which he could not well have at the villa outside the city. As if to dye his tragic fate still darker, he received the answer to this petition at the same moment that the physician told him of the approaching death of Maria Celeste. In the letter to Diodati above quoted, he says:—

"My grief at this terrible news was increased by another calamity. On returning home from the convent with the doctor who visited my sick daughter shortly before her death, and who had just told me that her situation was desperate, and that she would hardly survive till the next day (as indeed it proved), I found the Inquisitor's vicar here, who informed me of a mandate from the Holy Office that I must in future abstain from asking permission to return to Florence, or they would take me back to Rome, and put me in the actual prison of the Holy Office.[2] From this answer it

[1] Vagabond still, Vincenzio was at this time living in Florence in a house which his father had settled on him in the Via della Costa, and close to the Porta San Giorgio.

[2] This savage mandate was dictated by the Pope at a meeting held on 23rd March.

seems to me that in all probability my present prison will only be exchanged for that narrow and long-enduring one which awaits us all."

He then goes on to give his correspondent some interesting information which allows us to see a little behind the scenes of this terrible drama :—

"From this and other circumstances which it would take too long to describe, it will be seen that the fury of my powerful persecutors continually increases. They have, at length, chosen to reveal themselves to me. Thus, about two months ago when a dear friend of mine at Rome was speaking of my affairs to Father Cristoforo Griemberger, mathematician at the *Collegio Romano*, this Jesuit uttered the following precise words: 'If Galileo had only known how to retain the favour of the fathers of this college he would have stood in renown before the world, he would have been spared all his misfortunes, and could have written what he pleased about everything—even about the motion of the earth.' From this you will see, honoured Sir, that it is not this opinion or that which has brought and still brings about my calamities, but my being in disgrace with the Jesuits . . . .[1] Add to all this other troubles and many bodily infirmities which, without mentioning my age (more than seventy years), so overwhelm me that the least fatigue exhausts me and makes me ill. For all these reasons my friends must be indulgent and remember that that which at first sight seems to be negligence is in reality only powerlessness.

"But you, honoured Sir, who more than any other have wished me well, you will keep me in the affection of all my friends in Paris, especially of

Signor Gassendi whom I love and venerate so much. Please communicate to him the contents of this letter, and tell him also that I have received the dissertation of Signor Martius Hortensius [on the double motion of the earth], and that I have read it with the very greatest interest. If it please God to deliver me from a part of the evils which I endure at this moment, I shall not fail to answer his amiable letter.

"Berigard and Chiaramonti,[1] professors at Pisa, have written long works against me—the latter in his own defence; the former against his wish, as he says, but at the instigation of one who may be useful to him! A certain Jesuit father has printed at Rome that the opinion of the motion of the earth is of all heresies the most abominable, the most pernicious, the most scandalous; and that one may maintain in professorial chairs, in society, in public discussions, and in books, any and every argument against the principal articles of faith, against the immortality of the soul, against the creation, against the Incarnation, against everything, with one exception only—the dogma of the immobility of the earth! The title of this production is 'Melchioris Inchofer a Societate Jesu Tractatus Syllepticus.'[2] It

[1] This man was one of the most bigoted defenders of the old philosophy, and, as Montucla says, spent a long life in nothing but retarding as far as he was able the progress of science. He was one of the Commission appointed in 1632 to get up the case against Galileo. (See also footnote, p. 256 *ante.*)

[2] This work was lauded by his brother Jesuits "as differing so entirely from the pruriency of the Pythagorean writings." Quoting the first verse of Genesis as an argument that the earth was created after the heavens, he says the question is reduced to a purely geometrical problem. In the formation of a sphere does the centre or the circumference come first? If the latter, the consequence is inevitable, the earth is in the centre of the universe! The title-page of this book is decorated with an emblematical figure, representing the earth in a triangle; and in the three corners, grasping the globe with their fore feet, are the three bees of the Pope's arms, with the motto, "*His fixa quiescit*" (fixed by these it is at rest).

is from Rome also that Antonio Rocco writes in defence of the peripatetic philosophy, and with such little consideration for me. He acknowledges, himself, that he knows nothing of mathematics or astronomy. He has, in fact, not the least notion of the subjects on which he writes.[1]

"If God wills, I hope to publish my works on Motion, and other researches—all more important than those which have already appeared. This letter will reach you through my relative Roberto Galilei, to whom you might read it, as I have written to him only very briefly. . . ."

Full of labour and of sorrow his life had been, and full of labour and sorrow it was to continue to the end. Though crushed by grief for his daughter's death, the habits of industry acquired in youth, and maintained through life, could not be laid aside in old age. Work to his teeming mind was more than a consolation, it was a necessity. Thus it is that but a few months after Maria Celeste's death, we find him rousing himself, and eagerly at work again on his new Dialogues, wishing, as he told Diodati, that the world should see the last of his labours before his time of departure came. But, as he wrote, thoughts crowded thick and fast upon him, so that his work increased while each day lessened his span of life. "My restless brain goes grinding on," he wrote to Micanzio on 19th November 1634, "in a way that causes great waste of time, since the thought, which comes last into my head in respect of some novelty, drives out all that had been there before." He also

[1] For a list of anti-Copernican works published between 1632 and the time of Newton, 1668, see Martin's "Galilée," note B.

resumed his extensive correspondence with scientific friends. Unfortunately, few of his letters of this and the following year have come down to us, so that we can only infer the subjects from the answers of his correspondents.

While the prisoner of Arcetri was thus fulfilling his great mission, his friends took every opportunity of trying to obtain, at least, some extension of his liberty. Niccolini, Comte de Noailles (French Ambassador), and Niccolò de Peiresc (in letters from Paris), all interceded again and again with the Pope, but all to no purpose. His Holiness had soft words for all of them, but nothing was done.[1]

How deep was the undercurrent of bitterness in Galileo's heart when stirred by the remembrance of the Jesuits' machinations, his "wretched enemies," as he calls them, his correspondence of this period sufficiently shows. We give some extracts from his letter to Niccolò de Peiresc, 21st February 1635. After warm thanks for the noble though fruitless efforts of his friend, he goes on :—

"I have said, my Lord, that I hope for no alleviation, and this is because I have committed no wrong.[2] If I had erred I might hope to obtain grace and pardon, since the transgressions of the subject are the means by which the prince finds occasion for the exercise of mercy and indulgence. Wherefore, when a man is wrongly condemned to punishment, it becomes necessary for his judges to

[1] De Noailles was formerly a private resident pupil of Galileo at Padua, and de Peiresc was a friend of Pinelli at whose house Galileo often met him.

[2] "Forgiveness to the injured does belong,
But they ne'er pardon who have done the wrong."
—DRYDEN, *Conquest of Granada.*

use the greater severity in order to cover their own misapplication of the law. . . . Could all the frauds, the calumnies, the stratagems, the deceits, which were made use of at Rome eighteen years ago for the purpose of imposing on the supreme authority—could all these, I say, be brought to light, their only effect would be to enhance the purity and uprightness of my intentions. But you, having read my works, will have seen how they justify my assertion of sincerity, and you will have understood the true cause for which, under the mask of religion, I have been persecuted, and which now continually assails me and crosses my path, so that no help can come to me from without; nor can I undertake my own defence, all the Inquisitors having received express orders neither to allow the reprinting of my published works, nor to grant a licence for any fresh work I may wish to publish. Thus I am not only reduced to silence towards those who strive to distort my opinions, and so to make my ignorance (as they call it) manifest, but I must also bear the insults, the contempt, and the bitter taunts of men more ignorant than myself, without being able to utter a word in my own defence."

The Dialogues on The Two New Sciences (*i.e.* on Cohesion and Resistance to fracture, and on Uniform, accelerated, and projectile motion) were completed by the summer of 1636, and then arose the question of their publication. After his condemnation in 1633, the Holy Office placed his name in the list of authors whose writings *edita et edenda* were strictly forbidden, and so rigorously was this rule enforced, that Micanzio was not permitted to reprint the "Discourse on Floating Bodies," which did not in any way relate to the Copernican doctrines. Galileo tried Germany, and sent the

MS. to his friend Giovanni Pieroni in Vienna, only to find that all books printed there must first be sanctioned by the Jesuits, amongst whom at the moment Galileo's old antagonist, Father Scheiner, happened to be quartered. So Vienna would not do. Through the intervention of Cardinal Dietrichstein, Pieroni then got permission to print at Olmutz, with the approbation of a Dominican father, so that the business may be kept secret from Scheiner and his party. But very soon after, the Cardinal died, and, besides, Pieroni was not pleased with the Olmutz press, so the MS. was brought back to Vienna. A new approbation was procured (Scheiner having gone meanwhile into Silesia) and the work was on the point of being sent to the press when the dreaded Scheiner reappeared. Pieroni next took the MS. to Prague, where Cardinal Harrach offered him the use of the University press; but here again difficulties cropped up. Meanwhile Galileo, wearied with these delays, opened negotiations with Louis Elzevir through Micanzio in Venice, and, finally, the work appeared at Amsterdam in 1638.

It is clear from Galileo's correspondence that this edition was printed with his full concurrence, although, in order to obviate trouble with Rome, he pretended that it was pirated from a MS. copy which he had sent to Comte de Noailles, to whom the work is dedicated.

Rightly did Galileo, in his letter to Vinta of 7th May 1610, call his work in mechanics a new science invented by him from its very first

principles. That this is no exaggeration is shown by the following passage from the "Mécanique Analytique" of Lagrange, the great Italian Mathematician, and an undoubted authority on the subject:—

"Dynamics is the science of forces accelerated or retarded, and of the various movements which these forces can produce. This science is due entirely to the moderns, and Galileo is the one who laid its foundations. Before him philosophers considered the forces which act on bodies in a state of equilibrium only; and, although they could only attribute in a vague way the acceleration of heavy bodies, and the curvilinear movement of projectiles, to the constant action of gravity, nobody had yet succeeded in determining the laws of these daily phenomena on the basis of a cause so simple. Galileo made the first important steps, and thereby opened a way, new and immense, to the advancement of mechanics as a science.

"These discoveries did not bring to him while living as much celebrity as those which he had made in the heavens; but to-day his work in mechanics forms the most solid and the most real part of the glory of this great man. The discovery of Jupiter's satellites, of the phases of Venus, of the Sun-spots, etc., required only a telescope and assiduity; but it required an extraordinary genius to unravel the laws of nature in phenomena which one has always under the eye, but the explanation of which, nevertheless, had always baffled the researches of philosophers."

The Dialogue is carried on between the same speakers, Salviati, Sagredo, and Simplicio, as in

the "Dialogues on the Two Principal Systems of the World" (1632). The first two of the four Dialogues published in his lifetime are concerned with the "Resistance of Solids against Fraction," and the "Cause of Coherence in Solids." The ostensible object of the first discussion was scarcely reached, while the second contains little beyond an analysis of formulæ concerning the strength of beams. Their scientific value lies in the incidental experiments and observations on motion through resisting media.

The discussion opens with a short examination of the current belief that models built on exactly similar designs but on different scales were of strength in proportion to their linear dimensions. After exposing the error, Salviati enquires what is the nature of the force that holds up the lower part of a rod suspended from above. No complete explanation is forthcoming; but that suggested depends upon Nature's repugnance to the vacuum momentarily produced by the sudden separation of two flat surfaces. This leads to an experiment proposed by Salviati for measuring what he speaks of as the force of a vacuum.

This experiment occasions a remark from Sagredo that he had observed that a pump would not work when the water in the cistern had sunk 35 feet below the valve; that he thought the pump was injured, and sent for the maker, who assured him that no pump of that construction would lift water from so great a depth. This story is usually told as if Galileo had said jokingly that Nature's horror of a vacuum does not ex-

tend beyond 35 feet.[1] He evidently shared the common notion of suction, for he compares the column of water to a metal rod suspended from its upper end, which may be lengthened till it breaks by its own weight. It is remarkable that he failed to observe how simply this phenomenon may be explained by a reference to the weight of the atmosphere—a fact with which he was well acquainted, and, indeed, goes on in this dialogue to describe an experiment for determining the weight of air as compared with water.[2]

After a rather lengthy digression on the motion of a rolling circular hoop, in which Galileo brings forward some truths probably new at the time, but not essential to the main subject of the present dialogues, we come to more important matter in the discussion of motion through resisting media. This is introduced by some vague suggestions as to the nature of the action of heat on solid bodies, leading on to a short reference to light phenomena, which, Salviati insists, imply motion through a medium of some kind.

This statement introduces Aristotle's theory that bodies move with velocities proportional to their weights and inversely proportional to the densities of the media through which they are

[1] The first appearance of the story in this form has been traced to Pascal's "Traitez de l'equilibre des Liqueurs" (preface), Paris, 1663.

[2] Galileo's way of determining the specific gravity of the air was first described in his letter to Gio. Battista Baliani, dated 12th March 1613, now in the Brera Library, Milan.

moving. This proposition is examined in a strict scientific method. Heavy bodies of different weights are dropped in air to test the truth of the first part of the statement; and afterwards the motion of bodies rising or falling in liquids is considered; the result being to substitute for Aristotle's hasty assumption that law of the motion of falling bodies which is historically the foundation of the science of dynamics.

Two stones are dropped in air; their weights are respectively eight and four units. Aristotle's theory requires that the first shall travel with twice the velocity of the second; that, in fact, if the second have four, then, the first will have eight degrees of velocity. Salviati states that this does not agree with experiment; but he further reduces the *dictum* to an absurdity by considering the effect of fastening the two stones together. Common-sense would have it that the result would be a hurrying of the slower and a delaying of the faster traveller, producing a mean velocity of somewhere between four and eight velocity-units. Actual experiment would show that, according to the manner of fastening and the shape and distribution of weight in the stones, it might be possible to obtain a velocity slightly in excess of that of the heavier stone when falling alone. But neither common-sense nor experiment agrees with Aristotle's statement, according to which the compound body, now containing twelve units of weight, ought to travel with twelve units of velocity. So far, indeed, is Aristotle from the truth that Salviati asserts that if a stone weighing twenty

pounds and another weighing two pounds be dropped simultaneously from a tower 50 or 100 yards high, they will reach the earth at the very same moment.

"And I would not have you do as some are wont, who fasten upon some saying of mine that may want a hair's breadth of the truth, and under this hair seek to hide another man's blunder as big as a cable. Aristotle says that an iron ball weighing 100 lbs. will fall through a space of 100 yards while a weight of one pound is falling through a space of one yard. *I* say they will reach the ground together. *They* find the greater weight to anticipate the lesser by two inches, and under these two inches they seek to hide Aristotle's 99 yards!"

So Galileo satisfied himself that the current belief was wide of the truth; and that it was more nearly correct to say that heavy bodies, dropped through the air, fell with the same increasing velocities, whatever their weights, provided only those weights were sufficient to overcome with ease the air's resistance to their motion. He proceeds to examine the motion of bodies sinking or rising in water and other liquids; and he brings forward a group of experimental facts which, viewed in the light of Aristotle's statement, form a mass of contradiction. Putting this antiquated theory aside, Salviati enquires what is meant by the rising of some bodies in a medium, and shows that only those bodies rise which are lighter than the medium. The rising of an inflated bladder in the air suggests that the atmosphere must have weight. Simplicio's assertion that it is on the

contrary the bladder in this case that has levity is trivial, and is immediately disproved. Continuing his line of argument, Salviati points out that the question of rising or falling depends on the gravity of the medium as compared with that of the moving body; further, that when the motion of the body, either upwards or downwards, has once commenced, the different media offer different resistances to the motion, the heavier media, such as quicksilver and water, interfering more than air with the motion of a body; and we are thus led to the following summing-up by Salviati.

"We have found the difference of velocities in movables of different gravities to be more and more as the media are more and more resisting; thus, in a medium of quicksilver, gold does not only sink to the bottom more swiftly than lead, but it is the only thing that will sink in it, all other metals and stones moving upwards therein and floating on its surface. Whereas between balls of gold, lead, brass, or any other heavy matter, the inequality of their motion in the air shall be almost wholly insensible, so that, indeed, a ball of gold falling from a height of 100 yards in the end of its fall does not outstrip one of wax by four inches."

And then comes Galileo's bold, but justifiable deduction :—

"This being so, I have thought that if the resistance of the media be wholly taken away, all matter would descend with equal velocity."

This fundamental law once stated is amplified later on in the Dialogue, when Salviati explains that :—

"A heavy body has by nature an intrinsic force or principle of moving towards the common centre of heavy things (the centre of the earth) with a motion continually accelerated in such manner that in equal times there are always equal additions of velocity. This is to be understood as holding true only when all accidental and external impediments are removed, amongst which is one that we cannot obviate, namely, the resistance of the medium. This opposes itself more or less according as it opens slowly or speedily to make way for the moving body, which, being continually accelerated, encounters a continually increasing resistance in the medium, until at last the velocity reaches that degree and the resistance that power that they balance each other. All further acceleration is then prevented, and the movable continues for ever after with a uniform and equable motion."

The description of the motion of a falling body in the first Dialogue is followed by a reference to the oscillation of a pendulum; and this in turn leads to a digression, in which Galileo quotes a number of interesting experiments on sound. These it will be best for the present to pass over, as also the contents of the second Dialogue. The more important work in dynamics is resumed in the third and fourth Dialogues, on "Local Motion" and "Motion of Projectiles," the outline of which must be indicated in a few words.

No new physical facts of importance are quoted; these two Dialogues are mainly concerned with theorems and formulæ deduced mathematically from the phenomena explained in the first Dialogue. The discussion of uniform motion, however, involves a more emphatic statement than before of the prin-

ciple of inertia—that a body projected along a smooth horizontal plane would, if all resistances and external impediments were removed, continue to move uniformly along that horizontal plane for ever. Generalised, this statement would be equivalent to Newton's first law of motion. From the definition of uniform motion as that of a body which moves in one direction so as to cover equal spaces in equal intervals of time, Salviati proceeds to deduce the elementary formulæ, which his two listeners readily accept.

The definition of uniformly accelerated motion, however, at once introduces a difficulty. Salviati gives the correct description of it as that of a body which moves in such a manner that in equal intervals of time it receives equal increments of velocity. An alternative is suggested by Sagredo, and Simplicio—sympathising as usual with Sagredo's untenable propositions—is of course "of the number of those who allow that a descending body *vires acquirit eundo*"; in fact, that the increments of velocity should be specified in relation to the space rather than the time through which the body has travelled. They first appeared to think that the two statements would be equivalent and that theirs took the more direct form. It is pointed out by Salviati that the two are inconsistent, and he rightly conjectures that a direct reference of acceleration to the space described rather than to the time of travelling would lead to hopeless complications. He proceeds, accordingly, from his own definition to deduce formulæ connecting all these variable quantities—time of motion, velocity acquired, and space described—with one another.

An interesting application of the results obtained follows. He examines the times of descent down differently inclined planes, assuming as a postulate that the velocity acquired by a body falling down an inclined plane was the same for all planes of the same height. This fact he had verified by careful experiments, although he was unable at the time to account for it.[1] After the inclined plane comes an investigation of "lines of quickest descent"—a group of interesting problems, though not of essential importance in the development of the science of dynamics. Here he shows that the descent of bodies along an arc of a circle of less than 90° is shorter than the time occupied by the same bodies in traversing the chord of the arc—"which at first sight would seem to be a paradox, the arc being longer than its chord."

This investigation completed, the way is prepared for the subject of the fourth Dialogue. Sagredo, anticipating mathematical difficulties, begs for some preliminary instruction in the properties of the parabola, after which Salviati turns to the subject of projectiles, and lays down the law of the independence of the horizontal and vertical motions. A body projected horizontally would (but for its weight and "external impediments" which we suppose removed) continue to move; and Salviati contends that as the effect of gravity acting by itself would be entirely downwards, gravity acting on the hori-

[1] Viviani relates that soon after he joined Galileo, he drew his master's attention to this flaw in the argument. The same night, as Galileo lay in bed, sleepless through indisposition, he discovered the necessary mathematical demonstration. It was introduced into the subsequent editions of the Dialogues, Sixth "Day."

zontally projected body can neither increase nor diminish the rate at which it travels horizontally. Therefore, whatever be the shape of the path or the real direction of motion at any moment, the horizontal part of the motion is uniform, and the distance travelled horizontally may, therefore, be taken as a measure of the time that has elapsed since motion began.

Salviati proves that on this assumption the path described has geometrical properties which identify it with the curve known as the parabola. His demonstration is essentially that now given in works on elementary dynamics; the present account of the dialogues would, however, be incomplete without a quotation of the proof in Galileo's form.

MOTION OF PROJECTILE.

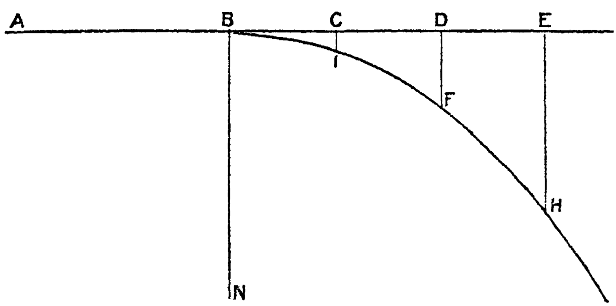



Fig. 9.

"Let A B represent a horizontal line or plane placed on high, on which let a body be carried with an equable motion from A towards B; and the support of the plane being taken away at B, let the natural motion downwards due to the body's weight come upon it in the direction of the perpendicular B N. Moreover, let the straight line B E (a prolongation of A B) represent the flow or

measure of the time, on which let any number of equal parts B C, C D, D E, be marked, and from the points C, D, E, let lines be drawn parallel to B N. In the first of these let any part C I be taken, and let D F be taken four times as great as C I; E H nine times as great, and so on. Now, if we suppose that whilst by its uniform horizontal motion the body moves from B to C, it also descends by its weight through C I, and at the end of the time denoted by B C it will be at I. In the time B D, double of B C, it will have fallen four times as far; for in the first part of this treatise it has been shown that the spaces fallen through by a heavy body vary as the squares of the times. Similarly, at the end of the time B E, or three times B C, it will have fallen through E H, and will be at H. Now, it is plain that the points I, F, H, are in the same parabolical curve B, I, F, H."

It only remains to verify whether the parabola as defined geometrically is actually the path of the moving body. This, as Salviati states, is true under certain conditions. Firstly, the path traversed must be of small dimensions as compared with the dimensions of the earth; this is necessary in order that the horizontal direction and the direction of gravity may be the same throughout the motion. And secondly, the resistance of the air so far modifies the motion, that the true parabola is only possible on the supposition that motion takes place *in vacuo;* the resistance of the air, however, is reduced to a minimum if we examine the motion of a heavy body of small dimensions travelling with only a moderate velocity.

After demonstrating the parabolic nature of the path, Galileo enquires into certain points of interest with regard to it, and gives proofs of many of the elementary propositions which in modern text-books are associated with parabolic motion. He also draws up a table giving the position and dimensions of the parabola described with any given direction of projection; finding by this means what he would have been unable to give a strict mathematical proof of—that the range on a horizontal plane is greatest when the angle of elevation is 45°.

The discussion of parabolic motion occupies the remainder of the Dialogue. Only one passage needs special mention. A bullet fired horizontally travels fast, yet not instantaneously; however rapidly it moves it takes time to travel even a short distance; therefore gravity will draw it downwards, though ever so slightly, below the horizontal line which was its original direction. If one would hit a mark, it is, therefore, useless to fire straight at it. Sagredo had noticed this, and remarks also on what it appeared to him might be an allied phenomenon—that a rope hanging between two points at the same height cannot be drawn absolutely straight however tightly it may be pulled. Salviati shows that this is due to the weight of the rope, just as the drop of the bullet is due to its weight. He continues as follows :—

"Besides, I must tell you that which at the same time will both amaze and delight you; 'tis this, that the rope, thus stretched more or less,

bends itself into lines very nearly parabolical. And the likeness is such, that if on a plane surface perpendicular to the horizon you describe a parabolic line, and turn it upside down, and to the extremities of the base of the described parabola you hold a chain or cord, by slackening it more or less you'll see it bend and fit itself to the same parabola. And this fitting shall be so much the more exact by how much the described parabola is less curved, *i.e.*, more distended; so that in parabolas described at elevations less than 45°, the chain agrees with them almost to a hair."

Galileo has sometimes been accused of having stated the curve of the suspended chain actually to be a parabola. From the passage quoted it is clear that the charge is unfounded. The catenary resembles the parabola; and, as Galileo justly remarks, the resemblance is very striking if the string is so far taut that the depth of the lowest point is less than a quarter of the distance between the two extremities. Galileo's theory of dynamics, which we have traced briefly, constitutes the more important part of the Dialogues on the "Two New Sciences."[1]

In order to preserve continuity, no reference has been made to the subject of the second Dialogue. It is an investigation of the strength of beams—an amplification of his researches on the same

[1] "In solving the problems of falling bodies and of projectiles, Galileo was essentially applying the principles of the Differential or Fluxional or Indivisible Calculus. If pure mathematics had attracted him as strongly as its application to physics, he would have thought these problems out, and would have founded the Fluxional Calculus, which is the glory of Newton and of Leibnitz." Professor Jack in "Nature," vol. xxi. p. 58. See note, p. 120 *ante*.

subject, dating back to 1609. Beyond Aristotle's remark that long beams are weak because they are at once the weight, the lever, and the fulcrum, nothing appears to have been written on the subject before Galileo took it up. In this he undertakes a problem which is far more intricate than he realised. A beam is fastened into a stone wall at one end and at the other supports a heavy weight; Galileo enquires into the strength of the beam to resist a snapping tendency. He assumes the point at which the fracture will take place to be close to the support. He further assumes that just before the moment of fracture the two parts of the beam will be holding together by means of a uniform force distributed uniformly over the section, as if the solid were equivalent "to a bundle of fibres," which were all strained equally in the direction of their length at the moment of snapping; and this although the fracture is assumed to begin at the top, the lowest fibre being the last to give way.

The curvature of a beam subject to any system of strains is a subject into which, before the days of Newton, it was impossible to enquire. And even in the simpler problem considered by Galileo, he makes assumptions which require justifying. Still, the discussion is interesting as the first serious attempt to examine this difficult statical problem. The formulæ obtained, if they are wanting in detail, prove that, however vague Galileo's ideas of force, he fully realised the mathematical fact underlying the theory of models—that if two frameworks are built on exactly the same plans but on different scales,

their strengths are not of necessity proportional to their dimensions.

On the subject of light, Galileo has left very little in theory; his best work in this field was the invention of the telescope with which his name is universally associated.

A suggestion in the first Dialogue that, perhaps, heat dissolves bodies by insinuating itself between their minute particles brings on the subject of light; on which Sagredo enquires whether we are to take for granted that the effect of light does or does not require time. Simplicio is ready with an answer, that the discharge of artillery proves the transmission of light to be instantaneous; to which Sagredo cautiously replies, that nothing can be gathered from that experiment except that light travels more swiftly than sound; nor can we draw any decisive conclusion from the rising of the sun. "Who can assure us that he is not in the horizon before his rays reach our sight?" Salviati then mentions an experiment by which he endeavoured to examine this question. Two observers are each to be furnished with a lantern; as soon as the first shades his light, the second is to uncover his, and this is to be repeated at a short distance till the observers are perfect in the practice. The same thing is then to be tried at the distance of several miles, and if the first observer perceive any delay between shading his own light and the appearance of his companion's, it is to be attributed to the time taken by the light in traversing twice the distance between them. He allows that he could discover no perceptible interval at the distance of

a mile, at which he had tried the experiment, but recommends that with the help of a telescope it should be tried at much greater distances.[1]

The only other subject remaining to be noticed is the application of the theory of the pendulum to musical concords and dissonances, which are explained, in the same manner as by Kepler in his "Harmonice Mundi," to result from the concurrence or opposition of vibrations of the air striking upon the drum of the ear. It is shown that these vibrations may be made manifest by rubbing the finger round a glass set in a large vessel of water; "and if by pressure the note is suddenly made to rise to the octave above, every one of the undulations, which will be seen regularly spreading round the glass, will suddenly split into two, proving that the vibrations that occasion the octave are double those belonging to the simple note." Galileo then describes a method he discovered by accident of measuring the length of these waves more accurately than can be done in the agitated water. He was scraping a brass plate with an iron chisel, to take out some spots, and moving the tool rapidly upon the plate, he occasionally heard a hissing and whistling sound, and whenever this occurred, and then only, he observed the light dust on the plate

[1] This was done some years later by the Florentine Accademia del Cimento, with the result that as the observers became more expert the interval became shorter, so that there was no reason to suppose that there was any interval at all. In short, light seemed to them to travel instantaneously. Roemer, the Danish astronomer, first calculated in 1675 the velocity of light, and found it to be about 200,000 miles per second, a close approximation to the modern figure, viz. 186,000.

to arrange itself in a long row of small parallel streaks equidistant from each other. In repeated experiments he produced different tones by scraping with greater or less velocity, and remarked that the streaks produced by the acute sounds stood closer together than those from the low notes. Among the sounds produced were two, which by comparison with a viol he ascertained to differ by an exact fifth; and measuring the spaces occupied by the streaks in both experiments, he found thirty of the one equal to forty-five of the other, which is exactly the known proportion of the lengths of strings of the same material which sound a fifth to each other.[1]

Salviati also remarks that if the material be not the same, as for instance if it be required to sound an octave to a note on catgut on a wire of the same length, the weight of the wire must be made four times as great, and so on for other intervals. "The immediate cause of the musical pitch is neither the length, the tension, nor the thickness, but the proportion of the numbers of the undulations of the air which strike upon the drum of the ear, and make it vibrate in the same intervals of time. Hence we may gather a plausible reason for the different sensations occasioned in us by different couples of sounds, of which we hear some with great pleasure, some with less, and call them accordingly concords, more or less perfect; whilst some excite in us great

[1] This beautiful experiment has been largely used in modern times by Chladni, Savart, and Wheatstone, with very interesting results.

dissatisfaction, and are called discords. The disagreeable sensation belonging to the latter, probably, arises from the disorderly manner in which the vibrations strike the drum of the ear; so that, for instance, a very harsh discord would be produced by sounding together two strings of which the lengths are to each other as the side and diagonal of a square, which is the discord of the false fifth. On the contrary, agreeable concords will result from these strings of which the numbers of vibrations made in the same time are commensurable, for then the cartilage of the drum does not undergo the incessant torture of a double inflexion which results from discordant percussions." The sense of pleasure in musical harmony involves questions which have yet to be answered. But Galileo's suggestion above has in it that degree of precision which distinguishes all his thought from that of the vague theorists of his day.

Something similar may be exhibited to the eye by hanging up pendulums of different lengths. "If these be proportioned so that the times of their vibrations correspond with those of the musical concords, the eye will observe with pleasure their crossings and inter-crossings recurring at appreciable intervals; but if the times of vibration be incommensurate, the eye will soon be wearied in following them."

No sooner was the MS. of these Dialogues out of his hands (summer of 1636) than Galileo's ever busy brain began to form new projects. "If I live," he wrote on 15th July 1636, to

Bernegger of Strasburg,[1] "I intend to put in order a series of natural and mathematical problems which I think will be as curious as they are novel." These were left unfinished, and now form the fifth and sixth Dialogues which were added to a later edition by Viviani after Galileo's death. The fragment of the fifth is on the subject of Euclid's definition of ratio (Book V. props. 5 and 7), and was intended to form a part of the third Dialogue, and to follow the first proposition on equable motion. The sixth Dialogue was intended to embody Galileo's researches on the force of Percussion, on which he was employed at the time of his death.

"In the last days of his life," says Viviani, "and amid much physical suffering, his mind was constantly occupied with mechanical and mathematical problems. He had the idea of composing two other Dialogues to be added to the four already published. In the first he intended to insert many new demonstrations and reflections on various passages in the first four Dialogues, besides the solution of many problems in Aristotle's physics. In the second he proposed to discuss, treating it geometrically, an entirely new science, viz. the wondrous force of percussion, which he claimed to have discovered, and which, he said, exceeded by a long way his speculations on the same subject formerly published" ("Vita di Galileo," 1654).

In these Dialogues in which Galileo recapitulates the results of his early mechanical researches

[1] The editor of the Latin edition of his Dialogues of 1632, which was brought out by the Elzevirs in 1635. The translation was really by Diodati of Paris, to whom Galileo had sent a copy of the work as first printed in Italian.

at Pisa and Padua, and of his life-long meditations, he does not formulate in definite laws the interdependence of force and motion. This was done for the first time by Newton at the beginning of his "Principia" (1687), and hence they are rightly called "Newton's Laws of Motion"; but in justice to Galileo it must be admitted that he not only prepared the way for Newton, but supplied him with much of his materials. Thus, the first law as stated by Newton—that a body will continue in a state of rest, or of uniform motion in a straight line, until it is compelled to change its state from some force impressed upon it—is a generalisation of Galileo's theory of uniform motion. Since all the motions that we see taking place on the surface of the earth soon come to an end, we are led to suppose that continuous movements, such, for instance, as those of the celestial bodies, can only be maintained by a perpetual consumption and a perpetual application of force, and hence it was inferred that rest is the natural condition of things. We make, then, a very great advance when we comprehend that a body is equally indifferent to motion as to rest, and that it equally perseveres in either state until disturbing forces are applied. Such forces in the case of ordinary terrestrial movements are friction and the resistance of the air; but where no such impediments exist, movement must be perpetual, as is the case with the heavenly bodies which are moving in a void, or something approaching it.

The second law—that every change of motion is in proportion to the force that makes the change,

and in the direction of that straight line in which the disturbing force is impressed—is involved in his theory of projectiles. Before Galileo's time it was a commonly received axiom that a body could not be affected by more than one force at a time, and it was therefore supposed that a cannon-ball, or other projectile, moves forward in a straight line until the force which impelled it is exhausted, when it falls vertically to the ground. Galileo's writings in the fourth Dialogue and elsewhere show the fallacy of this axiom, since he demonstrates that the path of the projectile, being the result of a combination of a uniform transverse motion and a uniformly accelerated vertical motion, must, apart from the resistance of the air, be a parabola.[1] The establishment of this principle of the composition of forces supplied a conclusive answer to the most formidable of the arguments against the rotation of the earth, and, accordingly, we find it triumphantly brought forward by Galileo in the second "Day" of his Dialogues of 1632.

The distinction between mass and weight was, however, not noticed, and, consequently, he failed to grasp that acceleration, which in the case of motion under gravity he so closely examined, might be made a means of measuring the magnitude of the force producing the motion. How far he was from this discovery may be gathered from a remark by Salviati incidental to the main argument, to the effect that when different bodies are falling freely

[1] In a vacuum it would be an ellipse. In fact, a projectile is a minute satellite of the earth, and *in vacuo* it would accurately obey all Kepler's laws.

towards the earth's centre, "the difference of their gravities has nothing to do with their velocities." Correct as this may be in the spirit in which it was meant, it shows that Galileo was yet far from anticipating in all its generality Newton's second law.

Of the third of the laws of motion—when a body exerts force on another, that other reacts with equal force; action and reaction are always equal and in opposite directions—we find traces in many of Galileo's researches, as in his theory of the inclined plane, and in his definition of momentum. It is also adumbrated in his "Della Scienza Meccanica" (1594), and in his latest ideas on percussion, which he was dictating to his disciples, Viviani and Torricelli, when seized with his last and fatal illness. But that he was *familiar* with the relation between the blow on one body and the reacting blow on the other or striking body cannot be maintained. There is no precise statement to justify such a supposition. Indeed, Galileo's ideas of *force*, as they have come down to us, are so vague that a statement, at the same time precise and general, cannot be expected.

Galileo's services were hardly less conspicuous in the statical than in the dynamical division of mechanics. He gave the first direct and entirely satisfactory demonstration of equilibrium on an inclined plane. In order to demonstrate this he imagined the weight and the sustaining power to be applied to the ends of a bent lever whose arms were of equal length and perpendicular to the vertical and slant sides of the plane; then reducing

the lever to a straight one, between the lines of direction of the weight and power, it was easy to prove that the forces *in equilibrio* on the plane were also *in equilibrio* on the lever, and were to one another as the length to the height of the plane.

By establishing the theory of "virtual velocities," he laid down the fundamental principle which in the opinion of Lagrange contains the general expression of the laws of equilibrium. And as regards that still obscure subject, molecular cohesion, he brought it for the first time within the range of mechanical theory.

As we have quoted Professor Playfair's appreciation of the Dialogues of 1632, to make up for the shortcomings of our own *résumé*, so with these still more admirable ones of 1638, we conclude with an extract which indicates the enduring value of Galileo's work in mechanics. Robert Grant, the distinguished astronomer, and author of the "History of Physical Astronomy," says:—

"The astronomical discoveries of Galileo, although remarkable for their brilliancy, derive their chief value from the support they lent to the Copernican theory, and the influence they exerted in overthrowing the false system of philosophy which then prevailed. But it is in his important researches relative to mechanical science that the genius of this great philosopher is most apparent. The science of motion could not, indeed, be said to have existed before his time, for the sole knowledge on this subject consisted of a few unintelligible maxims scattered through the works of Aristotle. It required no common degree of penetration to expose the errors which lurked amid the sophisms of the illustrious Stagirite; but a genius of a higher

order still was necessary to establish the clear and immutable laws of nature, in the room of the unmeaning subtleties of the schools. The sagacity and skill which Galileo displays in resolving the phenomena of motion into their constituent elements, and hence deriving the original principles involved in them, will ever assure to him a distinguished place among those who have extended the domains of science. It is, perhaps, impossible, in the present advanced state of mechanical philosophy, to form a just estimate of the difficulties which then interposed towards a precise and luminous view of the fundamental principles of motion. It is universally admitted that those phenomena which come under the daily observation of mankind, and which, on that account, do not possess any salient features on which the imagination can repose, are generally those which are most liable to elude the enquiries of ordinary minds. The principles which Galileo established by his sagacious researches had the effect of elevating mechanical science to the dignity of one of the most important subjects which can concern the attention of mankind. They were essential elements in the train of investigation which conducted Newton to the sublime discovery of Universal Gravitation; and, in fact, they constitute the basis upon which the vast superstructure of the physico-mathematical sciences has been reared." (Introduction, p. 11.)[1]

[1] Montucla ("Histoire des Mathématiques," Paris, 1758, vol. ii. p. 191) says: "I dare to assert that if any one merits the name of precursor to Newton it is Galileo and not Descartes." See also Professor Jack's lecture on "Galileo and the Application of Mathematics to Physics," "Nature," vol. xxi. pp. 40, 58.

## CHAPTER XVI

### GALILEO AT ARCETRI—HIS LAST WORKS

### 1636–1641

AFTER completing his "Dialogues on the Two New Sciences" (summer 1636), Galileo resumed his plan for determining longitudes by means of Jupiter's satellites, of which we have already said something in our Chapter VIII. The negotiations there described were resumed in 1620, and after dragging on spasmodically were finally given up in 1632. Now (August 1636), hearing that the Dutch merchants had offered a prize of 30,000 scudi to the inventor of a sure method of taking longitudes at sea, Galileo offered his plan to the States-General, his friend Diodati of Paris being the go-between, as he wished to keep the matter from the knowledge of the Inquisition officials.

As far back as 1612, Galileo had drawn up tables showing in advance the position of the satellites for several months, and these had been found to agree fairly well with subsequent observations of their actual positions. Since that time, amidst all his other employments,

he had for twenty-four years steadily continued his observations, with the object of bringing his tables to as high a state of accuracy as possible. This was the point to which the enquiries of the States, in accepting Galileo's offer, were chiefly directed. On 11th November 1636, the States appointed four Commissioners to communicate with him, and to report upon the various points on which they required information. They voted him a golden chain as a mark of their respect, and assured him that in case his plan proved successful he should have no cause to complain of their generosity. A long correspondence ensued, in the course of which Galileo entered into minute details with regard to the devices by which he proposed to obviate the practical difficulties attending his method.[1]

After much delay, caused partly by the secret and roundabout way in which the correspondence had to be carried on, and partly by Galileo's gradual failure of sight, Hortensius, one of the commission, was deputed to set out for Italy, in July 1638, to confer with Galileo in person; but the journey was put off at the last moment, as the following extract explains. We quote from a letter of Galileo to Diodati, dated 14th August 1638:—

"As ill-luck would have it, the Holy Office came to know of my negotiations with the States-General, which may do me great injury. I am, therefore, obliged to you for having induced

[1] See his letter to Lorenzo Realio, dated 6th June 1637.

Signor Hortensius to give up his intended journey, and thereby averted some calamity to me."

Soon after this, the brothers Ebers, Dutch merchants trading in Florence, were commissioned to deliver the golden chain and a letter from the States. On arriving at the house in Via della Costa where Galileo was staying (as will presently be explained), they found the old man in bed, ailing, and totally blind! He asked them to read the letter aloud, and to give him the box containing the chain. Taking it in his hands, he in a few measured words expressed his thanks to them for their courtesy, and to the States for the signal mark of honour they had shown him. The box and the letter he would keep, but the chain he begged them to take back, as he did not think it proper to retain it, seeing that, owing to his blindness and increasing infirmities, the negotiations must be postponed. Seeing, however, in the action of the States-General a proof of their desire to adopt his method, Galileo resolved to place all the papers containing his observations and calculations in the hands of Father Renieri, a former pupil and then professor of mathematics at Pisa, who was to finish and revise them, and then forward them to Holland. Before this was done a new delay was occasioned by the deaths in quick succession of every one of the four commissioners, Hortensius, the last, dying in April 1639. For two or three years the negotiations were entirely interrupted, and

were then renewed by Constantine Huygens, but very soon after, Galileo himself died, and again the business was interrupted. To complete the singular series of misfortunes by which the trial of this method was impeded, just as Renieri, by order of the Grand Duke of Tuscany, was about to publish the Ephemerides, he also was attacked with a mortal malady, and after his death the MSS. were nowhere to be found! For two hundred years they were supposed to be lost, but sixty years ago they were discovered amongst the Galilean Papers by Albèri, and may now be consulted in the fifth volume of his edition of Galileo's Works.[1]

Just before his sight began to fail, Galileo made his last astronomical discovery, which is now known as the moon's libration. A remarkable circumstance connected with the moon's motion is that the same hemisphere is always visible from the earth, showing that she turns once on her axis in exactly the time of her monthly revolution round the earth. Now, Galileo who, if we may say so, was quite at home in the moon, and was familiar with the whole of her visible surface, observed that small fringes of her other side come alternately into view and again recede, according to her position in the heavens.

This discovery was announced in a letter

[1] Renieri died in November 1647, when the longitude papers are supposed to have been stolen by one Giuseppe Agostini; but see Favaro's doubts on this subject in his "Documenti Inediti per la Storia dei MSS. Galileiani," Rome, 1886, pp. 8-14.

of 7th November 1637, to Micanzio, Venice, as follows:[1]—

"I see that you suppose I have not given up speculating. It is true I do go on speculating, but to the great prejudice of my health; for thinking, joined to various other molestations, destroys my sleep and increases the melancholy of my nights; while the pleasure which I have taken hitherto in making observations on new phenomena is almost entirely gone.

"I have observed a most marvellous appearance on the surface of the moon. Though she has been looked at such millions of times by such millions of men, I do not find that any have observed the slightest alteration in her surface; but that exactly the same side has always been supposed to be presented to our eyes. Now I find that such is not the case, but that she changes her aspect, as one who, having his full face turned towards us, should move it sideways, first to the right and then to the left; or should raise or then lower it; or, lastly, should incline it first to the right shoulder then to the left. All these changes I see in the moon; and the large anciently-known spots which are seen on her face will help to make evident the truth of what I say. Add to these a further marvel, which is that these three mutations have their several periods—the first daily, the second monthly, the third yearly. Now what connection does your Reverence think these three lunar periods may have with the daily, monthly, and yearly movements of the sea? which by the common consent of all philosophers are ruled over by the moon."[2]

Galileo was not long in detecting one of the

[1] See also his letter to Alfonso Antonini with the significant address "Dalla mio carcere di Arcetri, li 20 Febbraio 1637" (*ab incarnatione* = 1638).

[2] Compare pp. 171 and 259 on this subject of the tides.

causes of this apparent libratory or rocking movement. The diurnal or parallactic libration he saw was occasioned by our distance as spectators from the centre of the earth, which is also the centre of the moon's revolution. In consequence of this, as the moon rises we get an additional view of the lower part and lose sight of the extra portion of the upper part which was visible while we were looking down upon her when low in the horizon. The causes of the other motions noticed by Galileo are not so easily explained without a reference to mathematics. Nor is it certain that Galileo himself understood them; his conjecture of a connection with the tides is certainly wide of the mark.

The moon in revolving round the earth spins once on her axis in the time occupied by a revolution; so turning, as is well known, the same side always towards the earth's centre. But this familiar truth is only approximate. The speed of rotation is uniform; but the speed of motion in the orbit is not so, because that orbit is not a circle but more truly an ellipse, in which (as is always the case with elliptic motion) the moving body travels faster while near the centre of attraction than when farther away. The result is that we see alternately a little round the eastern edge, and a fortnight later a little round the western. Combined with this libration in longitude is a libration in latitude due to the fact that the moon's axis of rotation is not exactly perpendicular to the plane of its orbital motion, leaning a little towards us at one time, and a little away from us at the end of a fortnight. This enables us

to see at times a few hundred miles beyond the North Pole, and at other times a similar extent beyond the South Pole.

These two librations, though (as explained) due to independent causes, have approximately the same period—about one month. Their effects, however, vary according to the changing position of the earth in its orbit; and any particular phase of the libration is more nearly reproduced after twelve months than after one. Galileo was, therefore, justified in suggesting an annual period, although it is not customary at the present day to associate the annual period with any very distinct libration.

The complaint in his eyes, which began to be troublesome towards the middle of 1636, steadily grew worse for some months. By the end of June 1637, the sight of the right eye was gone, and that of the other was dimmed by a constant discharge. "I have been in bed for five weeks," he wrote to Diodati on 4th July, "oppressed with weakness and other infirmities from which my age (seventy-four years) forbids me to hope for release. Added to this (*proh dolor!*) the sight of my right eye—that eye whose labours (I dare to say it) have had such glorious results, is lost for ever. That of the left which was and is imperfect is rendered null by a continual running." But in spite of this affliction and his other sufferings (moral and physical) his interest in all things scientific was still unflagging. We find him carrying on an extensive correspondence with learned men in Germany, France, and Italy; continuing the negotiations with the States-General

about his longitude method; and filling up his leisure with astronomy and physics.

Early in December 1637 Galileo became totally blind. "The noblest eye is darkened," wrote Castelli, "which nature ever made—an eye so privileged and so gifted with rare qualities that it may with truth be said to have seen more than the eyes of all who are gone, and to have opened the eyes of all who are to come." His patience and resignation under this terrible calamity are truly wonderful; and if occasionally a word of complaint escapes him it is in the chastened tone of the following words, written to Diodati on 2nd January 1638:—

> "Alas! revered Sir, Galileo, your devoted friend and servant, has been for a month totally and incurably blind, so that this heaven, this earth, this universe, which, by my remarkable observations and clear demonstrations, I have enlarged a hundred, nay, a thousandfold beyond the limits universally accepted by the learned men of all previous ages, are now shrivelled up for me into that narrow compass which is occupied by my own person."

Hopes were entertained for a time that the blindness was occasioned by cataracts, and that he might hope for some relief from the operation of couching; but it soon became manifest that the disorder was not in the humours of the eye, but in a cloudiness of the cornea, which all remedies failed to alleviate.

Ever since his return to Arcetri from Siena, Galileo's friends in Rome lost no opportunity of interceding for him with the Pope, with a view to

his complete liberty from the galling restraints of the Holy Office. Besides the ever faithful Castelli and Niccolini, M. de Peiresc and Comte de Noailles, as we have seen (p. 345), took up his case in the warmest manner, and several times either themselves, or through the Pope's relatives, brought the matter before his Holiness in an urgent way. "They endeavoured," wrote Galileo to Micanzio on 12th July 1636, "to convince his Holiness that I never had such an iniquitous thought as to make game of him, as my wretched enemies had persuaded him, which was the prime motor of all my troubles. At length, the Holy Father pronounced my exculpation saying: 'We believe it, we believe it now,' but he added, all the same, that the reading of my Dialogues was most pernicious to Christianity."

In these negotiations the Cardinals Antonio and Francesco Barberini nobly seconded the efforts of Galileo's other friends. Indeed, if the Pope had meant more than fair speeches, there can be little doubt that the whole Congregation of Cardinals would have been ready to agree to Galileo's entire liberation—another proof, if one be wanted, of the vindictiveness of Urban personally.

At the end of September 1636, Galileo was allowed to visit the Grand Duke at his Villa Mezzomonte, outside Florence, going from Arcetri in a closed carriage in the early morning and returning late at night, so that he should not be seen on the way. Again, on 16th October, in the same year, he was allowed to go to Poggibonsi[1] to

[1] Poggibonsi was the meeting-place of another famous Florentine with another famous Frenchman. It was there, in June 1495, that

meet the Comte de Noailles on his way back to France. This was the extent of the Papal clemency for many months.

But now, on hearing of his blindness and many infirmities, the Pope seemed to have relented a little his savage treatment of the poor old man. Father Castelli was given to understand that a suitable petition would now be entertained, and on 9th January 1638, he sent a draft one which Galileo was to copy and return, with a medical certificate, direct to the Assessor of the Holy Office in Rome. This was done at once, but it was not enough. The local Inquisitor in Florence was instructed to see Galileo and make an exact report as to his health, and as to the likelihood, if he lived in Florence, of his promoting or encouraging there the propagation of his errors. The Inquisitor, Father Fanano, reported as follows, on 13th February 1638, to Cardinal Francesco Barberini:—

"In order the better to execute his Holiness's commands I went myself, accompanied by a strange physician, to see Galileo quite unexpectedly. My idea was not so much to put myself in a position to report on the nature of his ailments as to gain an insight into the studies and occupations he is carrying on, that I might be able to judge whether he was in a condition, if he returned to Florence, to propagate the condemned doctrine of the double motion of the earth. I found him entirely blind. He hopes for a cure, as the cataract only formed six months ago; but at his age, of over

Savonarola met King Charles VIII. of France on his skedaddle from Naples, and by prophetic denunciations kept him from looting Florence.

seventy [74] the physician considers it incurable. He has besides a severe rupture, and suffers from continual weariness of life and sleeplessness which, as he asserts (and it is confirmed by the inmates of his house), does not permit him one hour's sound sleep in the twenty-four. He is besides so reduced that he looks more like a corpse than a living man. The villa is a long way from the city, and the access is inconvenient, so that he can but seldom and with much inconvenience and expense have medical aid. His studies are interrupted by his blindness, though he is read to sometimes; and intercourse with him is not much sought, as in his poor state of health he can only complain of his sufferings and talk of his ailments to occasional visitors. I think, therefore, in consideration of this, if his Holiness in his boundless mercy should think him worthy and would allow him to live in Florence, he would have no opportunity of holding meetings, and if he had he is so prostrated that I think it would suffice (in order to make quite sure) to keep him in check by an emphatic warning."

This report at last seems to have softened the Papal heart, but only a little bit. A partial relief was decided on at a sitting of the Congregation on 26th February, under the presidency of the Pope, a full release to this man "more like a corpse," appearing too dangerous to be ventured on! On 9th March, Galileo was allowed to enter Florence and occupy his son's little house, No. 11 Via della Costa, near the gate San Giorgio. Here the Inquisitor called and informed him, "for his advantage," of the orders of the Holy Office—not to go out in the city, under pain of actual imprisonment for life and excommunication; not to speak

with any one whomsoever of the condemned doctrines; and not to receive any suspicious visitors. It is characteristic of the ways of the Inquisition that Fanano set Galileo's own son to watch over his movements. The Inquisitor enjoined upon Vincenzio to see that his orders were obeyed, and, especially, to see that his father's visitors did not stay too long. In his report to Rome of 10th March he remarks that Vincenzio can be trusted, "for he is greatly obliged for the favour granted to his father to be medically treated in Florence, and fears that the least offence might entail the loss of it. Besides, it is very much to his own interest that his father should behave properly, and keep up as long as possible, for with his death a 1000 scudi will go, which the Grand Duke allows him annually."

Galileo's confinement in Florence was so rigorous that at Easter a special permission from Rome was required to go to the little Church of San Giorgio, one hundred yards down his street, to perform his Easter devotions, and even this permission only extended to Thursday, Good Friday, Saturday, and Easter Sunday. On the other hand, it would seem that he was allowed during June, July, and August, to go to and fro between his house in Via della Costa and his villa at Arcetri.

During the summer of 1638, Galileo gradually sank so low that he and every one about him thought that his last hour was approaching. In this belief he dictated his will on 21st August, and directed that he should be buried in the family vault of the Galilei in the Church of Santa Croce,

Florence. To his daughter Sister Arcangela (who survived him seventeen years) he left an annuity of 25 crowns; to his nephews Vincenzio, Alberto, and Cosimo Galilei,[1] he bequeathed 1000 crowns, which, however, he revoked in a codicil added a few months later (19th November). He willed that any of his descendants who might enter a religious Order were to be by such act deprived of the enjoyment of any of his property that might come to them. His son Vincenzio was to have the rest, and, in the event of his death during the minority of his three children, their mother Sestilia, *née* Bocchineri, was to be guardian jointly with his faithful disciple Mario Guiducci.

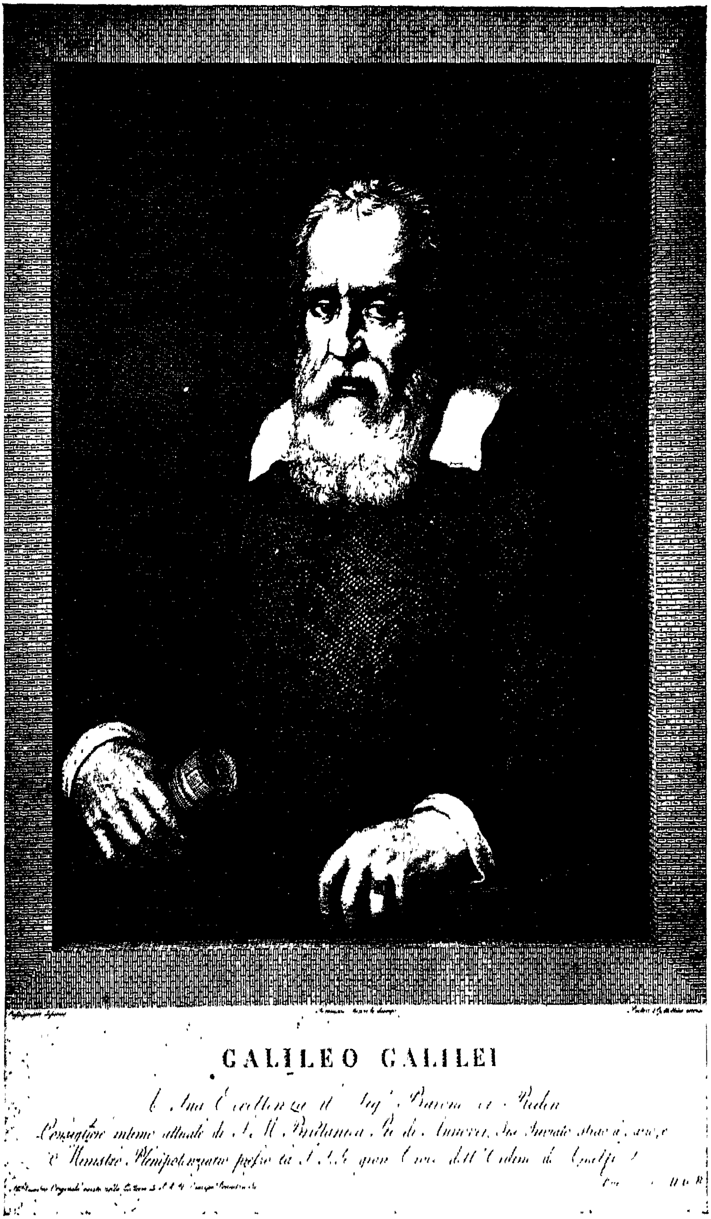
Early in September the Grand Duke paid his sick Philosopher and Mathematician a visit of two hours' duration, and helped to prepare his medicines. These kindly visits were repeated more than once either by the Sovereign himself, who used to say, "I do so because I have only one Galileo," or by some member of the Medici family.[2]

[1] At this time Alberto, "il Grazioso Albertino," as Maria Celeste always called him, was staying with his uncle on a long visit. Of Michelangelo's large family but three sons now remained, Vincenzio, who was teacher of music and singing to some Polish prince, Alberto, lute and violin player in the service of the Duke of Bavaria, and a younger boy, Cosimo, whom Alberto was maintaining. The wife, a son, and three daughters, all are supposed to have perished in the sack and burning of Munich a few years before (1634).

[2] These visits are recorded on a white marble slab over the entrance door as follows :—

Qui ove abitò Galileo
Non sdegnò Piegarsi alla Potenza del Genio
La Maestà di Ferdinando II.
Dei Medici

In the little garden at the back of the house is an old sundial, said to be the work of Galileo.




Portrait of Galileo, aged about 75.

[*To face p.* 384.

It had been for a long time Galileo's wish to have with him in the evening of his life his favourite disciple and lifelong friend Father Castelli, and as it was now supposed that his days were few, the Grand Duke sent the following instructions to his Ambassador in Rome, in a despatch from Cioli, on 9th September 1638 :—

"Signor Galileo, from his great age and the illnesses which afflict him, is in a condition soon to go to the other world; and although in this the eternal memory of his fame is already secured, yet his Highness is greatly desirous that the world should sustain as little loss as possible by his death, and that his labours may not perish, but, for the public good, may be brought to that perfection which he will not now be able to give them. He has in his thoughts many things worthy of him which he cannot be prevailed on to communicate to any but Father Benedetto Castelli in whom he has entire confidence. His Highness wishes, therefore, that you should see Castelli, and induce him to procure leave to come to Florence for a few months for this purpose, which his Highness has very much at heart. And if he obtains permission, as his Highness hopes, you will furnish him with money and everything he may require for his journey."

Niccolini replied that Castelli had been himself to the Pope with this object; that his Holiness, suspecting his design was to see Galileo, taxed him with it; and upon Castelli stating that certainly he could not go to Florence without attempting to see him, he received permission to visit him, but only in the company of an officer of the Inquisition.

Early in October Castelli reached Florence, and was at once permitted to visit his old master, but was expressly prohibited under pain of excommunication to converse with him on the condemned doctrines. Finding, as he did very soon, that the local officials of the Holy Office were inclined to curtail his interviews with Galileo, Castelli wrote repeatedly to Rome to obtain greater liberty. He protests in these letters that he would rather lose his life than converse on subjects forbidden by the Church, and gives as a reason for more frequent interviews that he had received from the Grand Duke the twofold charge, to minister to Galileo in spiritual matters, and to inform himself fully about the Ephemerides of the Medicean Stars, which Giovan. Carlo de Medici, Lord High Admiral, wished to take with him to Spain. Early in November, the necessary permission arrived, "in consideration of these circumstances, and under the known conditions."

In January 1639 Galileo's general health was said to have so far improved as to permit of his returning to Arcetri, which he was never to leave again till death. Was this move a voluntary one? it may be doubted. In the first place, it is difficult to reconcile a voluntary return to his villa with his previous efforts to obtain permission to live in Florence. Then, there are many of his letters which bear the expressive addresses "Rusculo meo" (17th August 1634), "Mio Carcere di Arcetri" (4th and 15th March 1635, 9th February 1636, 4th March 1637, and

20th February 1638), and "Dalla Villa Arcetri, Mio continuato Carcerede Esilio" (20th January 1641). From such considerations it is allowable to conclude that Galileo would have little pleasure in going back to his "prison," and, therefore, that his banishment from the city was not voluntary, but the result of orders from Rome.[1]

Some time after his return to Arcetri, Galileo would appear to have solicited some favour from Rome which was inexorably refused. After this he came no more into direct contact with the Roman authorities, as he now gave up all hope of any amelioration of his lot from the implacable Pope. "As it pleases God, so also it should please us," was the refrain of many of his letters. Father Castelli also had by this time come to the conclusion that nothing more could be done for his unfortunate master, for henceforth we find nothing in his letters but scientific disquisitions and spiritual consolations.

The rest of Galileo's life was spent at Arcetri, where indeed, even if granted full liberty, his age and infirmities would probably have detained him a prisoner. The rigid manner in which the Holy Office had hitherto shadowed

[1] The Pope was kept fully informed of Galileo's doings by the local Inquisitor, and, doubtless, the publication of his Dialogues "in a heretical country," his negotiations about the longitude, "with heretical Hollanders," and the rumoured offer of a professorship in the "heretical" Athenæum in Amsterdam, were not pleasing indications for his Holiness. The idea, at his advanced age and with shattered health, of retiring to Holland shows how much Galileo must have felt the restraints imposed upon him in his own country.

him was now relaxed, and he was generally permitted to see the friends who came to express their respect and sympathy. The Grand Duke, as we have seen, or some member of his family, visited him frequently, and many distinguished strangers, such as Gassendi and Diodati of Paris, came into Italy solely for the purpose of testifying their admiration of his genius. Amongst the names of other *Oltramontani* is that of a young Englishman, who was able to give him the gratifying information that his Dialogues of 1632 were being eagerly read by the learned men in England. This was John Milton, then in his twenty-ninth year, and already known as a poet of great promise. Milton left England for the Continent some time in April 1638, and reached Paris early in May; thence travelling by way of Nice, Genoa, Leghorn, and Pisa, he arrived in Florence early in August. Masson, in his "Life of Milton," has collected what little we know of this visit. The young poet was enthusiastically received by the members of the Accademia della Crusca, and assisted at many of their reunions. "In the private academies of Italy," he says, "whither I was favoured to resort, some trifles which I had in memory, composed at under twenty or thereabouts, met with acceptance above what was looked for; and other things, which I had shifted, in scarcity of books and conveniences, to patch up amongst them, were received with written encomiums which the Italian is not forward to bestow on men of this side the Alps."

The only specific reference by Milton to his visits to Galileo occurs in the following passage in the "Areopagitica," a discourse addressed to the Lords and Commons against the proposed licensing of printed books:—

"I could recount what I have seen and heard in other countries, where this kind of Inquisition tyrannizes, when I have sat among their learned men (for that honour I had) and been counted happy to be born in such a place of philosophic freedom, as they supposed England was, while themselves did nothing but bemoan the servile condition into which learning amongst them was brought; that this was it which had so dampt the glory of Italian wits, that nothing had been written there now these many years but flattery and fustian. There it was that I found and visited the famous Galileo, grown old, a prisoner to the Inquisition for thinking in astronomy otherwise than the Franciscan and Dominican licensers thought."

Milton is said to have first met Galileo some time in September 1638, in which case the meeting probably took place in the little house in Via della Costa. The poet left Florence, *via* Siena, early in October, for Rome, where he spent the winter, paying a short visit to Naples. Early in March 1639, he returned to Florence, where, according to his own account, he was received with no less eagerness than if the return had been to his native country and friends at home. On this occasion he stayed two months, and Masson believes that he saw Galileo again and, probably, more than once.

These meetings would certainly have taken place at the villa in Arcetri.

"There unseen
In manly beauty Milton stood before him
Gazing with reverent awe—Milton—his guest,
Just come forth, all life and enterprise;
*He* in his old age and extremity,
Blind, at noonday exploring with his staff;
His eyes upturned as to the golden sun,
His eyeballs idly rolling. Little then
Did Galileo think whom he received;
That in his hand he held the hand of one
Who could requite him—who would spread his name
O'er lands and seas—great as himself, nay, greater;
Milton as little that in him he saw,
As in a glass, what he himself should be,
Destined so soon to fall on evil days
And evil tongues—so soon—alas, to live
In darkness, and with dangers compassed round,
And solitude."[1]

Another great Englishman, Thomas Hobbes of Malmsbury, during his travels abroad, 1634-37, spent some time in Florence, *circa* 1635-6, and often met his brother philosopher for whom he conceived and ever retained the warmest admiration.[2]

The French philosopher Descartes was, probably, the only great man who, finding himself in Florence, did not honour himself by calling on Galileo. Arago tells us that during his wanderings Descartes visited parts of Italy and returned to France (1625), passing through the capital of Tuscany. He adds—"One would be astonished to learn that he had no wish to be presented to

[1] Rogers' *Italy* (the Campagna of Florence). The meeting of Milton and Galileo is the subject of a long poem by Giacomo Zanella. "Versi," Florence, 1868.

[2] See Galileo's letter to Micanzio, dated 1st December 1635.

Galileo, did we not know that by an inexplicable aberration he was always indifferent to the works and admirable discoveries of the Italian philosopher."[1] In the same way, during his previous peregrinations in Germany, as a soldier of fortune, Descartes would not see Kepler, although he called him his master in optics.

During the summer of 1639 Vincenzio Viviani, then eighteen years old, came to live with Galileo and remained with him to the end, glorying in the title of "ultimo suo discepolo." Almost from the first day a strong attachment sprang up between the two, the old master conceiving a fatherly affection for the talented youth, and the pupil, a love and veneration for the master which he preserved through life. In his old age when in his turn he had acquired a claim to the reverence of another generation, our Royal Society, in electing him a member (1696), appear to have felt that the complimentary language in which they addressed him as the first mathematician of the age would be incomplete without an allusion to the friendship that gained him the cherished title of "the last disciple of Galileo."

Early in 1640, the peripatetic Professor in Padua, Fortunio Liceti, published a book on the phosphorescence of the Bologna Stone, so called from its discovery in 1602 by Casiorolo, a shoemaker and alchemist of Bologna. In his fiftieth chapter he treats of the faint light of that part of

[1] He used to say that he saw nothing in the writings of Galileo to make him envious, and hardly anything which he would care to call his own. See Martin's "Galilée" pp. 290 and 311.

the new moon not directly illuminated by the sun, holding that the moon was phosphorescent like the Bologna Stone, and rejecting Galileo's explanation that it arises from a reflection of the sun's rays from our earth to the moon and their re-reflection from the moon back to us. Galileo was undecided whether it were not best to take no notice of Liceti's objections, when a letter from Leopoldo de Medici, brother of the reigning Grand Duke, relieved him of his doubts. This prince, who some years later gained a permanent place in the history of science by founding the celebrated Accademia del Cimento, solicited Galileo's views on Liceti's arguments, This challenge sufficed to rouse all his dialectic skill, and he dictated a reply (13th March 1640) in the form of a letter to Prince Leopoldo, which in spirit and crushing argument, is quite equal to the best controversial work of his manhood. An extract will serve to show the difficulties of this composition.

"I am obliged to have recourse to other hands and other pens than mine since my sad loss of sight. This of course occasions great loss of time, particularly now that my memory is impaired by advanced age, so that on placing my thoughts on paper, many and many a time I must have the foregoing sentences read to me before I can tell what ought to follow; else I should repeat the same thing over and over again. Your Highness may take my word for it that between using one's own eyes and hands and those of others there is as great a difference as between playing chess with one's eyes open and blindfolded."

This letter of fifty (printed) pages led to a

correspondence with Liceti, covering the period from June 1640 to January 1641. The letters are full of science and philosophy, and are pervaded by a verve, an urbanity, and a piquant irony, which make them refreshing reading even to-day. In them he not only deals with the arguments and pretensions of his adversary, but he delivers his opinions very freely on the whole method of Aristotle and of the modern peripatetic school of his debased followers. The correspondence ended in Galileo sending a revised copy of his letter to Prince Leopoldo to Liceti, which the latter printed in 1642 together with his reply.

Ten months before his death, a last occasion of discussing the Copernican theory was in a manner forced upon Galileo. The mathematician Pieroni having announced the discovery of a small annual parallax for some of the fixed stars (which, if true, would place the correctness of the Copernican theory beyond all question), Francesco Rinuccini, a former pupil, communicated this intelligence to his old master on 23rd March 1641, and at the same time begged his opinion on a recently published argument against the revolution of the earth, namely, since we see exactly one-half of the firmament, it must follow that the earth is in the centre of the starry sphere. This was the impulse to Galileo's reply of six days later (29th March), which, as Martin and Von Gebler say, whether a jest or a mask, should never have been written. He begins by saying that the falsity of the Copernican doctrine can in no way be doubted, especially by Catholics, since we have opposed to

it the irrefragable authority of Holy Scripture, as interpreted by the greatest masters of theology, whose unanimous declaration makes the stability of the earth in the centre, and the mobility of the sun around it, a certainty. This so resembles the ironical style of his letter of 1618 to Prince Leopold of Austria when forwarding his treatise on the tides, the introduction to his Reply to Ingoli in 1624, and his preface to the discreet reader in his Dialogues of 1632, that it cannot be taken as seriously meant. He then goes on, as at the end of the Dialogues just mentioned:—

"The grounds on which Copernicus and his followers have maintained the contrary fall to pieces before the fundamental argument of the Divine Omnipotence. For, since this is able to effect by many, aye, by endless means what, so far as we can see, appears practicable in one way only, we must not limit the power of God, and persist obstinately in our mistaken notions. As I hold the Copernican theory to be insufficient, so, that of Ptolemy, Aristotle, and their followers, appears to me far more delusive and mistaken, because its falsity can be clearly proved without going beyond the limits of human knowledge."

The Copernican theory being thus condemned, and the alternatives, those of Ptolemy and Tycho Brahé being demonstrably untenable, it only remains, he says, for philosophers to find some other system of which both science and theology can approve. Then coming to the new argument against the mobility of the earth which so troubled his correspondent, he shows that it is a mere *petitio principii*,

and has not the least foundation in astronomical science; and, finally, as to the reported discovery of a stellar parallax, he says briefly that if Pieroni's observation be correct, human reason would compel us to conclude that the earth is not immobile in the centre of the starry sphere. But, as if repenting his audacity in saying this, he hastens to add, "If Pieroni may be mistaken in supposing that he had observed a parallax of a few seconds, those others may be still more mistaken who assert that the visible firmament never varies, not even one or two seconds, for such an exact observation is utterly impossible, partly from the insufficiency of astronomical instruments, and partly from the refraction of light."

Cesare Cantù and some writers after him have assumed from this letter that at the close of his life Galileo had really renounced, and from pure conviction, the astronomical doctrines for which he had laboured and suffered for thirty years. But if we bear in mind all the circumstances under which the letter was written, we will see that this assumption is quite untenable, and that we must conclude with Martin and Von Gebler that the passages on which Cantù and his followers rely were not meant to be taken *au pied de la lettre*—that they were, as Martin puts it, "la protestation habilement ironique d'une pensée contrainte à se cacher." [1]

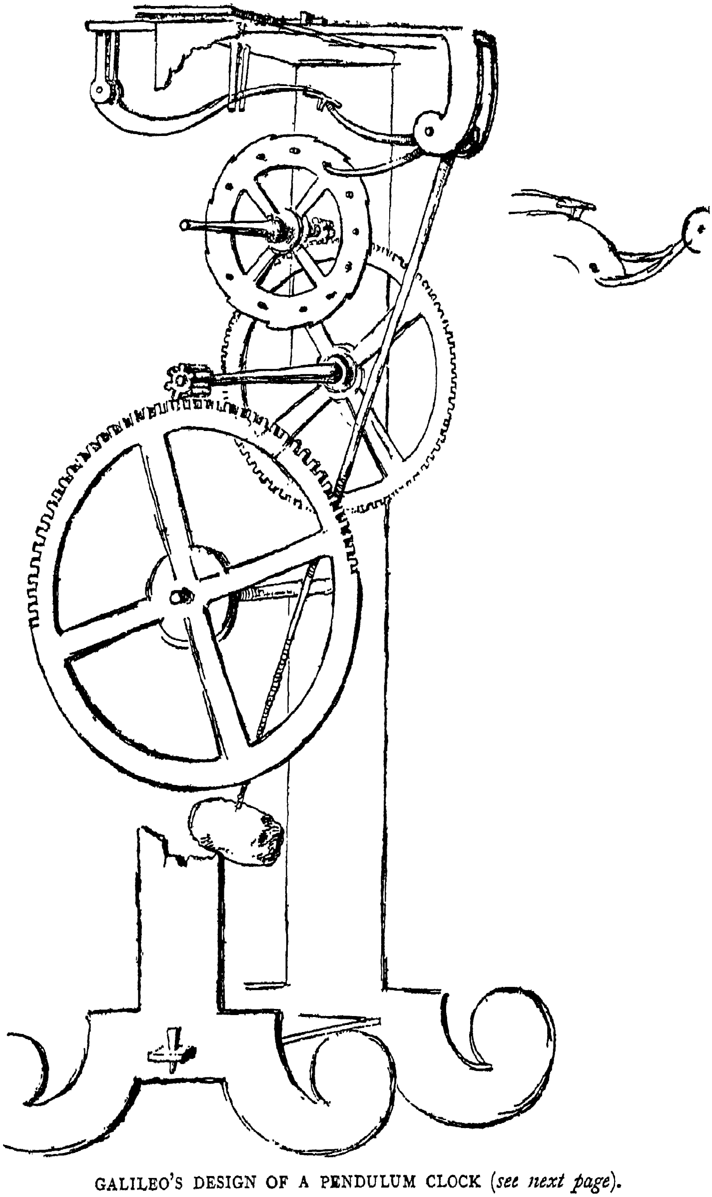
A few months before his mortal illness Galileo once more gave evidence of his genius. It has been remarked in the progress of science and

[1] Martin's "Galilée," p. 235; Gebler's "Galileo and the Roman Curia," p. 305.

scientific invention that the steps, which on looking back seem the easiest to make, are often those which are the longest delayed. The application of the pendulum to clocks is an instance of this. We have seen that Galileo was early convinced of the value of the pendulum as a measurer of time, and that as far back as 1582 he used it in the pulsilogia; yet fifty-five years later, although constantly using it meanwhile, he had not devised a more practicable application of it than that described in his "Astronomical Operations," 1637-8.

"I make use of a heavy and solid pendulum of brass or copper, in the shape of a sector of twelve or fifteen degrees, the radius of which may be two or three palms (the greater it is the less trouble in attending it). This sector I make thickest in the middle radius, tapering gradually towards the edges, where I terminate it in a tolerably sharp line, to obviate as much as possible the resistance of the air, which is the sole cause of its retardation. This sector is pierced in the centre, through which is passed an iron bar shaped like those on which steelyards hang, terminated below in an angle, and placed on two bronze supports. If the sector (when accurately balanced) be removed several degrees from the perpendicular, it will continue a to-and-fro motion through a very great number of vibrations before coming to rest; and in order that it may continue its oscillations as long as it is wanted, the attendant must occasionally give it a smart push so as to carry it back to large oscillations.

"Now to save the fatigue of continually counting the oscillations, this is a convenient contrivance—a small delicate needle extends from the middle of the



GALILEO'S DESIGN OF A PENDULUM CLOCK (*see next page*).

From Favaro's "Galileo e Cristiano Huygens. Nuovi documenti sull' applicazione del pendolo all' orologio" (*Nuovi studi Galileiani*, Venice, 1891).

sector which in passing strikes a rod hung at one end. The lower end of this rod rests on the teeth of a horizontal wheel as light as paper. The teeth are cut like those of a saw. The rod striking against the perpendicular side of a tooth moves it, but when returning it slips over the oblique side of the next tooth and falls at its foot, so that the motion of the wheel will be in one direction only. By counting the teeth you may see at will the number passed, and, consequently, the number of oscillations or periods of time which you wish to measure. You may also fit to the axis of the wheel a second, with a smaller number of teeth and in gear with a third wheel having a greater number of teeth, and so on. As the error of clocks consists chiefly in the inability of mechanicians to adjust what we call the balance of the clock so that it may vibrate regularly, my very simple pendulum, which is not liable to any alteration, affords a means of maintaining the measures of time always equal."

It was chiefly because of the inadequacy of this method that the negotiations with the States-General were finally broken off. Now, in the second half of 1641, it occurred to Galileo (as stated by Viviani who was present) that the problem could be solved by adding the pendulum to the ordinary clock as a regulator of its movements. He explained his idea to his son, Vincenzio, who made a drawing (of which we reproduce a facsimile) from his father's dictation. Before the plan could be tried Galileo fell ill, and this time did not recover. The matter was laid aside, but seven years after his father's death, Vincenzio resumed it, and was engaged in constructing what would have been the first

pendulum clock, when he too fell ill and died, 16th May 1649.[1]

[1] For more on this interesting subject, see Viviani's account which he wrote expressly, 20th August 1659, for Prince Leopoldo de Medici in Albèri's vol. 14. The application of the pendulum to clocks has been claimed for the Swiss, Burgi, and for Richard Harris of London in 1611; but Christian Huygens appears to have been the first to actually construct a pendulum clock between 1654 and 1657.

# CHAPTER XVII

## DEATH OF GALILEO—CONCLUSION

### 1642

THE last few months of Galileo's life were soothed by the devotion of his friends, and the homage of all to whom his name was known. The Grand Duke was most attentive in enquiries after his health, and sent him supplies of his choicest wines and other delicacies. Besides the creature comforts thus supplied, Galileo had the pleasure of once more meeting his old friend Castelli, and discoursing with him on the things of that world to which they both were tending. The good Father arrived from Rome towards the end of September 1641, intending to stay to the end, but he had to return to his duties early in November.

Towards the middle of October, Evangelista Torricelli, then a rising philosopher of thirty-three, came to stay at the villa, and did not leave it until he followed the coffin of the great master. Torricelli first studied under Castelli, and, later on, occasionally lectured for him in Rome, in which manner he was employed when Galileo, who had seen his early treatises on mechanics and on the motion of fluids, and had augured the greatest success from such beginnings,

invited him to Arcetri. He succeeded the master in his appointment at the Court of Florence, but survived him only a few years, dying in 1647, at the early age of thirty-nine. The youthful Viviani, as we know, was already in the villa, acting as a loving son to an honoured father. He, Torricelli, and Vincenzio Galilei shared between them the duties of amanuensis and companion.

On the 1st October, Bonaventura Cavalieri, another of Castelli's distinguished pupils, whom Galileo used to call "another Archimedes," wrote from Bologna, expressing his grief at not being able, on account of his infirmities, to join the distinguished company; and another lifelong friend and champion, Fra Fulgenzio Micanzio of Venice, to whom Galileo had written in praise of his new *collaborateur*, replied on 2nd November in similar terms; he envied, he said, the reunions of such an illustrious triumvirate, Galileo, Castelli, and Torricelli.

On 5th November, Galileo was attacked by a low fever with pains in the limbs, which confined him to bed from which he never rose again. Yet in spite of these sufferings, aggravated by insomnia, and by frequent attacks of palpitations of the heart, his mind was clear and busy to the last, and in the intervals of pain he passed hours in scientific discussions with Torricelli and Viviani who carefully noted his utterances. These related to the Mechanical Problems of Aristotle, to his long contemplated (since 1609) Treatise on the Movements of Animals, to the properties of the cycloid, but chiefly to the force of percussion. His notes

on the first three subjects have not come down to us, but those on percussion now form the sixth Dialogue added to the later editions of the "Dialogues on the Two New Sciences," as already explained.

On the evening of 8th January 1642, the year of Newton's birth, Galileo breathed his last, at the age of nearly seventy-eight, fortified by the last rites of the Church, and the benediction of Urban VIII. His son Vincenzio and his wife, Torricelli and Viviani, and the parish priest of Arcetri were around his bed.

Not only was his power of making a will disputed, but the propriety of laying his body in consecrated ground was questioned by some fanatics, who could only see in the life of this great man the one fact, that he had died under sentence of the Holy Office, "vehemently suspected" of heresy. On a reference to the proper authorities, his power of making a will was upheld, and it was also ruled that his friends had full right to place his remains in consecrated ground.

Accordingly, preparations were at once made for a public funeral such as might best show the sense of the Court and the city of the greatness of their loss, and the sum of 3000 crowns was quickly collected to cover the expense of a marble monument in the Church of Santa Croce. These and other particulars were reported to Rome, whereupon the Pope sent for the Tuscan Ambassador, Niccolini, and desired him to tell his master that it would be a bad example for the world if such honours were rendered to a man

who had been arraigned before the Holy Office for false and erroneous opinions; who had communicated them to many others; and, altogether, had caused the greatest scandal to all Christendom. Niccolini, reporting this interview on 25th January 1642, advised that the project of a funeral oration and a monument be laid aside, at least for a time; since, as his Holiness claimed to be absolute master of all churches and consecrated grounds, it was likely that an insistence on these public honours would draw on the Grand Duke himself some such affront as was offered, not long before, to the Duke of Mantua (by the removal of the body of the Countess Matilda from Mantua to St Peter's in Rome).[1] So determined and threatening was the Pope's attitude in this matter that the weak Ferdinando II. was not able to resist. Proposals both for a public funeral and a monument were laid aside, and the friends of the great dead were constrained to hide away (there was not even an epitaph) his beloved remains in a little room or cell (9 feet by 6) to the right of the altar in the Chapel of the Novices, situated at the end of the corridor leading from the south transept of Santa Croce to the great sacristy.[2] It was not till nearly thirty-two years later (September 1673) when Urban VIII. had long

[1] At the same time the Inquisitor in Florence was instructed to make similar representations to the Grand Duke; and if without the desired effect, he was to see that there was nothing in the epitaph that could be construed as an insult to the Holy Office, and he was to exercise the same care in the preparation of the funeral oration.

[2] Here were also laid in 1703 the remains of Viviani who desired to lie beside his master.

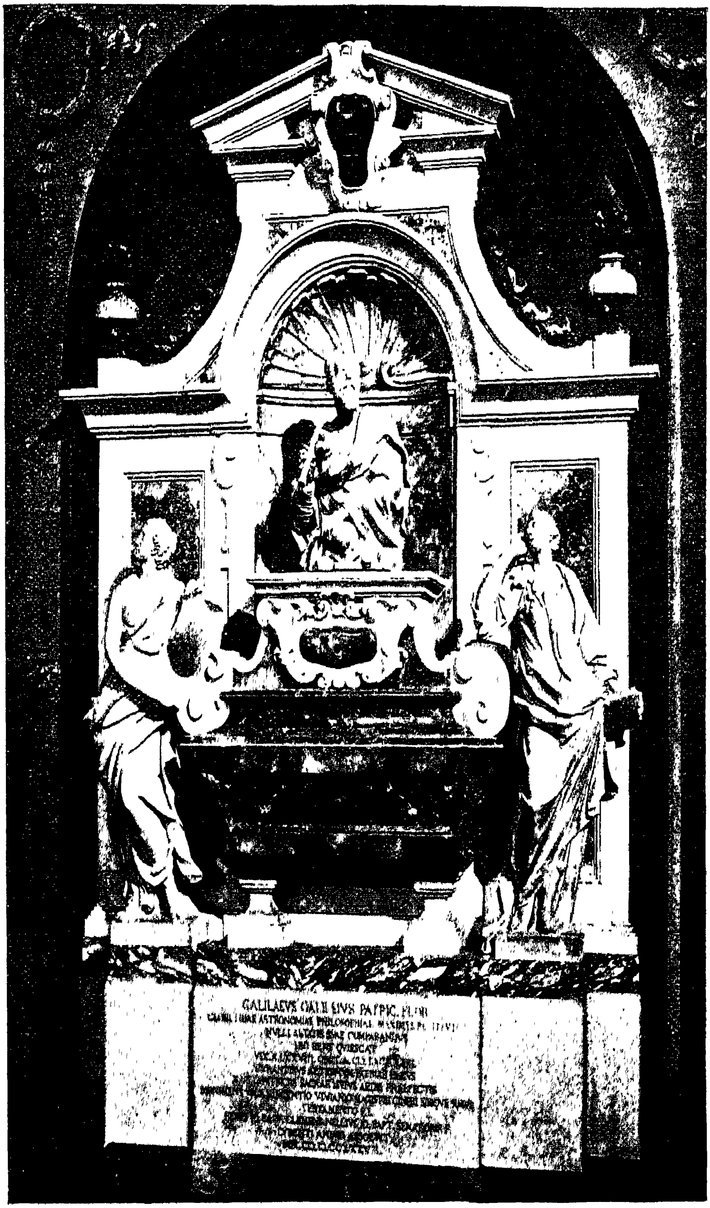
been dead, that Father Gabriele Pierozzi of Santa Croce ventured to honour the illustrious dead by painting on the wall of the cell a somewhat bombastic inscription, and placing on a plaster bracket above it a small bust of Galileo in clay, painted in imitation of marble. The bust was removed in 1737, at the translation of Galileo's remains (to be presently described), but the inscription remains, partly obliterated, and in a fair way of disappearing, by the scaling of the plaster.[1]

In 1693, Viviani ventured to erect the first public monument to Galileo. On the front of his house in Via dell' Amore (now Via San Antonino), he placed a bronze bust of the philosopher, which was cast from a mould of a terra-cotta bust made in 1610 by Giovanni Caccini, the sculptor, by desire of Cosimo II. Over this and on both sides of the entrance door, on large marble scrolls, are engraved long eulogies of the master.[2]

But Viviani was not content with these pious memorials. Dying in 1703, he left his property to his nephew, the Abbe Jacopo Panzanini, charged with the condition of erecting a suitable monument in bronze and marble as soon as permission to do so could be obtained. For over thirty years no attempt was made to carry out his wishes, and then the business was taken in hand,

[1] Brewster ("Martyrs of Science") gives a copy of this inscription, but not quite accurately. See Albèri's "Opere di Galileo," vol. xv. p. 405.

[2] For these, see Albèri's vol. xv. pp. 373-80. Viviani had also caused a medal to be struck in honour of Galileo; and no less than five other commemorative medals were issued during his residence in Padua and Florence. All of these are reproduced in Nelli's and Venturi's works.



Galileo's Monument in Santa Croce, Florence.

[*To face p.* 404

not by Viviani's heir, but by the executor Gio. Battista Nelli. In 1734, enquiries were made at Rome as to whether there was any decree of the Holy Office which would prevent the erection of a monument. The reply, 16th June 1734, was that there was nothing against such a proposal, provided the intended inscription were submitted for approval. The work was accordingly taken in hand, but dragged on slowly for nearly three years. Finally, on the night of 12th March 1737, and in presence of the leading clergy, of all the professors of the schools of Florence and Pisa, and of learned, literary, and artistic men from all parts of Italy, Galileo's remains were removed with great pomp to the mausoleum in the north aisle of Santa Croce—the Pantheon of the Florentines — whither also were conveyed the remains of Viviani, according to his last wishes.

The monument, which we reproduce from a photograph, is the work of Gio. Battista Foggini, assisted by his son, Vincenzio, and Girolamo Ticciati. The bust of Galileo and the figure representing astronomy are the work of Vincenzio Foggini, while the figure of geometry is from the chisel of Ticciati.

> "In Santa Croce's holy precincts lie
> Ashes which make it holier, . .
> . . . . . . . . . here repose
> Angelo's, Alfieri's bones, and his
> The starry Galileo, with his woes;
> Here Machiavelli's earth returned to whence it rose."
> —Byron, *Childe Harold*, Canto IV. 54.

Galileo's old resting-place was about two yards

high, and consisted of rude masonry, built on the floor and against the wall of the cell. Viviani's was close beside it, of similar structure but smaller. On breaking away the stonework of the latter, which it was found convenient to remove first, and on opening the coffin, a lead plate was found, attached to the inside of the lid, on which was inscribed—

"Vincenzio Viviani Morto il di xxii Settembre 1703."

The cover was then replaced, and the coffin was transferred to its new resting-place.

Returning to the little chapel, the masonry of Galileo's tomb was removed, and the coffin laid open. Giovanni Targioni-Tozzetti, one of the pall-bearers, tells us that the face was well preserved, and like the bust by the sculptor Caccini, made in 1610, and also very like Sustermans' portrait, *circa* 1635 (a copy of which forms the frontispiece of the present work). A heavy iron girdle was found in the coffin, so fashioned as to lead Targioni-Tozzetti to suppose that the wearer must have suffered from rupture on both sides. It was also observed that the body was pierced, probably to let escape an accumulation of water, and the opening was filled with coarse wadding. This seems to indicate dropsy, which must, therefore, be added to the poor old man's other maladies.[1]

During the work of exhumation and identification Canon Gio. Vin. Capponi, President of the Sacra Accademia Fiorentina, took an opportunity

[1] Targioni-Tozzetti: "Notizie degli Aggrandimenti delle Scienze Fisiche in Toscana," Florence, 1780.

of removing with a knife the thumb and forefinger of Galileo's right hand! because, as he said to Targioni-Tozzetti, they held the pen with which so many fine things were written; but the latter (who tells the story in the work just quoted) tapped the skull, and said he would rather have some of the brains which conceived the grand thoughts. These relics were still preserved in the Capponi family down to 1845, and are now apparently lost.

Soon after, Anton. Francesco Gori, Professor of Ancient History in the University of Florence, removed the index finger of the left hand, which, at his death, passed to Canon Angelo Bandini. At his death in 1803, it came into the custody of the Laurenzian Library (of which Bandini had been Keeper), and in 1841 it was transferred to its present place in the Tribuna di Galileo in Florence. It is enclosed in a crystal urn, and bears an inscription from the pen of Tommaso Perelli, a celebrated astronomer of Pisa, *circa* 1770—

> "Leipsana ne spernas digiti quo dextera coeli
> Mensa vias nunquam visos mortalibus orbes
> Monstravit, parvo fragilis molimine vitri
> Ausa prior facinus cui non Titania quondam
> Suffecit pubes congestis montibus altis
> Nequidquam superas conata ascendere in arces."

At the same time, yet another idolater, Dr Antonio Cocchi, Professor of Natural Philosophy and Anatomy, took away the fifth lumbar vertebra, which, after passing through many hands, came into the possession of Dr Thiene. In 1823, he presented it to the University of Padua, where it is now preserved in the museum attached to the physical science laboratory.

From Viviani's biography of Galileo (1654) we learn that he was of a cheerful and pleasant countenance, especially in later life, square of frame, well-proportioned, and rather above the middle height. His complexion was fair and sanguine, his eyes sparkling, and his hair and beard, of which he had an abundance, of a reddish hue. Up to the age of thirty his constitution was sound, but after his first serious illness in 1593 he was beset by various complaints, which increased in gravity and frequency as the years rolled on. Thus for nearly fifty years he was subject to frequent attacks of fever, hypochondria, and rheumatism, and, latterly, to gout, rupture, and insomnia. Yet, with such a multitude of complaints as would have made a miserable valetudinarian of any other man, his industry was extraordinary. It was said that no one had ever seen him idle, and one of his favourite sayings was that occupation is the best medicine for both mind and body.

His temper was what we would call short; he was easily ruffled, but more easily pacified—a condition which, if not produced, was certainly aggravated by physical suffering, and the troubles of all kinds, public and private, from which for sixty years he was seldom free.

In his younger days he was fond of a country residence. Besides believing that the city air was prejudicial to his health, he was wont to say that the city was in a manner a prison for the speculative philosopher; that in the country alone was the book of nature open to him who cared to read and learn from it; that the characters in which

that book was written were those of geometry; and that when once they were fully deciphered we might hope to penetrate the deepest mysteries of nature.

Though he loved the quiet of a country life, he was fond of the society of friends, to whom he constantly dispensed a hospitality simple but hearty. Gardening in all its forms was his favourite and almost his only relaxation from the severe studies which filled his days, and great part of his nights. He was a connoisseur in wines, and was diligent in tending his own vineyard. He used to say that wine is a compound of humour and light; and Viviani has preserved one of his recipes —for wine of the best quality, that juice only should be taken which is pressed out by the mere weight of the heaped grapes of the ripest kind.

All through life he was fond of wine, perhaps sometimes too fond for his health and temper,[1] and even in old age the taste was apparently as keen as ever, as the following curious letter will show. It is headed "From my prison at Arcetri," and is dated 4th March 1637—

"I am forced to avail myself of your assistance, agreeably to your obliging offers, in consequence of the excessive chill both of weather and of old age, and from having drained out my grand stock of a hundred bottles which I laid in two years ago—not to mention some minor particulars during the last two months which I received from my serene master, from the Cardinal de Medici, the princes, and the Duke of Guise; besides clearing out two barrels of the wine of this country. Now I beg that, with

[1] See Favaro's "Galileo e Suor Maria Celeste," p. 141.

all due diligence and industry and taking counsel with the most refined palates, you will provide me with two cases, *i.e.* forty flasks of different wines, the most exquisite that you can find. Take no thought of expense, because I stint myself so much in all other pleasures that I can afford to lay out something at the shrine of Bacchus, without giving offence to his two companions Venus and Ceres. You must be careful to leave out neither Scillo nor Carino (I believe they should be called Scylla and Charybdis), nor the country of my master Archimedes of Syracuse, nor Greek wines, nor clarets, etc. The expense I shall easily be able to satisfy, but not the infinite obligation I shall owe you."

In other expenditure Galileo observed a just mean between avarice and prodigality. He spared no cost necessary for the success of his many and various experiments, and spent large sums in charity, and in assisting those in whom he discovered promise of any kind, many of whom he entertained in his own house. Even in the last year of his life, he had one such poor scholar in the Villa, as may be seen from Cesare Monti's letter of 30th May 1640, and Galileo's reply of 2nd November following.

He seldom conversed on mathematical or philosophical topics, except with his intimate friends; and when such subjects were abruptly brought before him by others, as was often done by the numerous strangers who called upon him, he showed great readiness in parrying and turning the conversation into other channels, in such manner, however, that he usually contrived

to say something to satisfy the curiosity of the enquirer. His demeanour, therefore, was modest and unassuming. Of self-praise so much is recorded of him that, when his sight was decaying beyond all hope of recovery, he used to comfort himself by saying that of all the sons of Adam none had seen so much as he. He neither depreciated nor envied the talents of other men, but gave to each his due, according to his own lights. It was the custom of many of his followers to speak of Aristotle with contempt, not so the master, he would only say that the methods of reasoning of the great Stagirite philosopher appeared to him unsatisfactory, or erroneous; and such of the works of Aristotle as he did admire, he admired frankly, especially those on Ethics and Rhetoric. He exalted Plato to the skies, calling his eloquence golden. Pythagoras, he thought, unequalled among philosophers; but Archimedes was the only one of the ancients whom he called master. Much of Virgil, Ovid, Horace, and Seneca, he knew by heart.

His memory was uncommonly tenacious, and was stored with a variety of old songs and stories which he would bring out on all suitable occasions—The Sonnets of Petrarch, the Rime of Berni, and the heroic stanzas of the "Orlando Furioso" he could repeat in great part. As we have already seen in our Chapter II, his excessive admiration of Ariosto determined the side which he took against Tasso in the virulent controversy which had divided Italy so long on the merits of these two poets. It should, however, be

remembered that his matured taste receded from the violence of his youthful prejudices, and, towards the end of his life, he avoided as much as possible making any comparisons, and, when forced to give an opinion, he would say that Tasso's appeared the finer poem, but that Ariosto's gave him greater pleasure.[1]

Of his *obiter dicta*, not many have been preserved. Besides those already noted, one or two others may be quoted. The book of philosophy, he used to say, is the book of nature which lies always open before us, and is written in characters of geometry. Not to know, then, geometry, is to be ignorant of nature. Another favourite axiom, conveying the same truth, was *Ignorato motu ignoratur natura*. When the understanding has experience to inform it, reason is not indispensable, was another of his sayings. He was wont to say that he had never met with a man so ignorant that something might not be learnt from him; again, that ignorance in others was his best teacher, for in learning how to combat ignorance he taught himself. He used to say that it was the privilege of the sad and miserable not to be envied by the merry, and of the wicked, not to be envied by the good.

As a teacher he was no less loved and valued than as a friend. However clear a subject might be to his own mind, he was not satisfied till he made it as clear to the minds of his pupils. "From Signor Galileo," wrote Marsili (in 1637),

[1] See his letters of 5th November 1639 and 19th May 1640, to Francesco Rinuccini.

"I learnt more in three months than I did in as many years from other men." "I thank God," said Paolo Aproino, "for having given me for master the greatest man the world has ever seen." "When," wrote Ciampoli, after his retirement in disgrace to Montalto in 1633, "When shall I embrace you as a father and listen to you as an oracle?" Viviani and Gherardini are equally enthusiastic; and even some of his stoutest adversaries, as Lagalla and Grassi, readily admitted his greatness in this respect.

Pages might be filled with expressions of gratitude and devotion such as these culled from the letters of Galileo's disciples. And truly the master himself might adjudge them to be of higher value, as a testimony to his greatness, than the marble monument under which he now reposes in the Church of Santa Croce.

On the occasion of the third congress of scientific men in Italy, held in Florence in 1841, the Tribuna di Galileo was opened by Leopoldo II., the last Grand Duke of Tuscany. It is on the first floor of the Museum of Physics and Natural History, a building which the scientific visitor to Florence should not fail to explore; for, besides the exquisite little temple of Galileo, it contains a vast and splendid collection of scientific apparatus of all kinds, for the most part the remains of the once famous Accademia del Cimento.

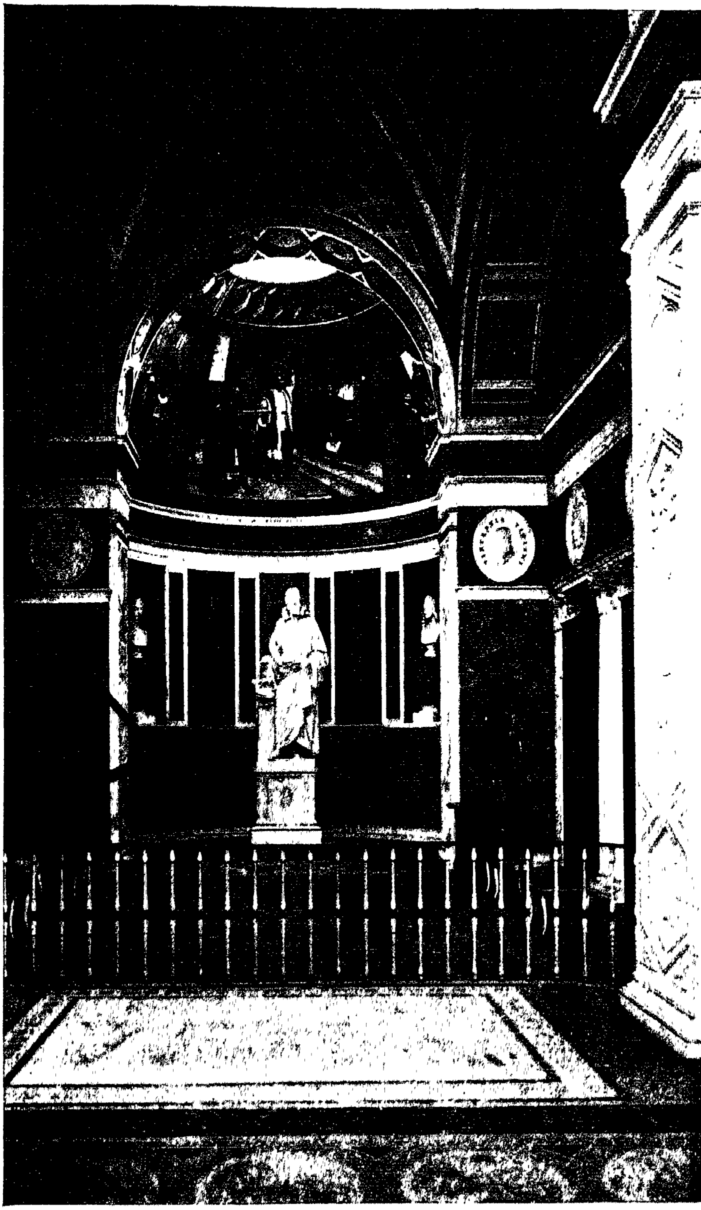
An extract from the official Guide,[1] will sufficiently explain the design:—

[1] "Guide de la Tribune de Galilée," Florence, 1843. It was reprinted in 1861, and has long been out of print.

"The temple being dedicated to the memory of the great Galileo, the father of experimental philosophy, and being destined to preserve the scientific instruments, etc.—the products of his genius, and of that of his school, it was desired that it should be, at the same time, commemorative of the most famous epochs of Tuscan philosophy, and of the men who made them famous. And, in order to preserve the distinctively national character of the work, it was decided that only Tuscan artificers and Tuscan materials should be employed in the building and decorating. Thus the architect, Giuseppe Martelli, was Tuscan, and the artificers, the painters, and the sculptors were all Tuscan."

The building, which is said to have cost £40,000, consists of (1) a vestibule which is lighted on the left by a fine stained-glass window, and from which opens, on the right, (2) a small rectangular hall, which leads to (3) a semi-circular tribune. The interiors are entirely lined with white marble, and profusely decorated with frescoes, medallions, busts, and drawings carved in low-relief and illustrative of the discoveries and inventions of Galileo and his immediate followers.

In the centre of the tribune stands the statue of Galileo by Professor Costoli; and in compartments of the domed ceiling above the statue are three frescoes, depicting three momentous periods of his life—the rising, the zenith, and the setting of his genius. In the first, we see the youthful Galileo watching intently the swinging lamp in the Cathedral of Pisa. In the second, he is presenting his telescope to the Doge of Venice. In the third, old and blind, he is seated at a table, with his left hand on a globe,



Tribuna di Galileo, Florence.

[To face p. 414.

and discoursing to Torricelli and Viviani; the parish priest of Arcetri, and Galileo's father confessor, are seen listening at the open door.

In the (semi-circular) wall of the tribune are six niches; the first, second, fifth, and sixth, contain busts of Castelli and Cavalieri, Torricelli and Viviani, the two first and the two last disciples of Galileo. In the third niche one sees, through a glass frame, two of Galileo's later telescopes, and the object-glass of *the* telescope with which he made all his astronomical discoveries; we have reproduced a photograph of these precious relics to face p. 96. In the fourth niche, also glass-covered, are seen (1) a geometrical and military compass, (2) a loadstone with Galileo's armature, and (3) the index finger of his left hand.

In *lunettes*, above the walls of the vestibule and rectangular hall, are four large frescoes. One, which faces the visitor on entering the temple, shows Leonardo da Vinci in presence of Ludovico Sforza, Duke of Milan, to whom he is enumerating his numerous inventions. In the opposite *lunette* Volta is seen explaining his electric pile to the members of the French Institute, Napoleon and Lagrange being prominent amongst the spectators. The corresponding paintings in the hall represent (1) Galileo in Pisa proving the law of descent of falling bodies by experiments on an inclined plane, and (2) Viviani, Borelli, and Redi showing to the Grand Duke the apparent (but to them real) reflection of cold by a parabolic mirror. A thermometer is seen in the focus of the mirror, and a block of ice is used as the source of cold.

On the pilasters are fourteen white marble medallions of members of the Accademia del Cimento, and other distinguished Italian scientists. And on pedestals in the vestibule are busts of the Grand Duke, Ferdinando II., the friend of Galileo, and a patron of science; of Prince Leopoldo, his brother, also a great friend of Galileo, and founder of the Accademia del Cimento; of Grand Duke Pietro Leopoldo I., founder of the Museum of Physics and Natural History; and of Grand Duke Leopoldo II., under whose auspices the temple of Galileo was erected. Scattered over the vaulted roofs or ceilings are ten small paintings, emblematic of nature, truth, perseverance, physics, philosophy, astronomy, geometry, mathematics, hydraulics, and mechanics.

On the floor of the hall, on stands, are four instruments of great size: a brass astrolabe; an odometer or distance-measurer; a movable dial by Rinaldini, mounted in walnut, with a Tychonic scale in brass; and the great crystal lens of Bregans of Dresden, with which Averani and Targioni-Tozzetti, and, many years later, our own Sir Humphrey Davy made experiments on the combustion of the diamond and other precious stones. Finally, in large glass cases, lining the walls of the hall and vestibule, are preserved the most interesting specimens of the instruments, etc., belonging to the famous Accademia del Cimento, such as thermometers, barometers, hygrometers, gravity-meters, globes for experiments on the compressibility of water, telescopes by Torricelli, Viviani, and other early Italian makers; and collections of chemical

(beautiful specimens of Florentine glass-work), astronomical, nautical, and geodetic apparatus.[1]

In 1864, the tercentenary of Galileo's birth was celebrated at Pisa, in a way which, if the news could have reached him, would have gone far to make amends for her ill-treatment in the flesh of her most famous graduate and professor.[2]

On 7th December 1892, a far more imposing ceremony took place in Padua, to commemorate the three-hundredth anniversary of Galileo's first lecture in that renowned seat of learning. We base the following account of this historical function on an article in "Nature," 22nd December 1892.

"On 6th December, the rector, Professor C. F. Ferraris, received in one of the courts of the old University (adorned everywhere with portraits of the most illustrious professors) delegates from the universities, the polytechnic schools, and Italian and foreign academies, amounting to nearly a hundred, and among them many who shed most lustre on contemporary science. The University of Cambridge was represented by Professor George Howard Darwin, F.R.S., who also represented the Royal Society, as Mr Norman Lockyer, its delegate, had been prevented from attending. The University of Oxford by Professor E. J. Stone;

[1] At the foot of the stairs leading to the Tribune is a fine statue of Torricelli in white marble, but it is practically hidden in a small sombre recess. Surely the Museum authorities could find a more suitable place.

[2] See "Il terzo Centenario di Galileo," by Professor Benedetti, Pisa, 1864, or *Giornale di Pisa*, 21st February 1864. On 2nd October 1839, a fine marble statue of Galileo, by Emilio Demi, was unveiled in the University. The figure, larger than life, is sitting, in professor's gown, and holds a globe in the left hand. A partly unrolled scroll (showing astronomical figures) rests on the knee, and the right hand is slightly extended as if in the act of demonstrating.

the Royal College of Physicians, London, by Sir Joseph Fayrer, F.R.S.; the Chemical Society and British Association by Professor Ludwig Mond, F.R.S.; the Harvard University, Cambridge, U.S.A., by Professor William James, and the Princeton University by Professor Allan Marquand.

"The great academical celebration took place on 7th December in the large hall of the University, in the presence of Signor Ferdinando Martini, Minister of Public Instruction, who represented the King of Italy. The ceremony was begun with a discourse, prepared for the occasion, by the rector magnifico, and devoted principally to a cordial expression of thanks to the king and to the minister who represented him; to the foreign and Italian delegates; and to the ladies of Padua, who had given the University a most beautiful banner, on which were various emblems indicating the history of the University, the genealogical tree of the Galilei family, and the ancient inscription above the door of the University—*Gymnasium omnium disciplinarum.*

"Next came the commemoration of Galileo by Professor Antonio Favaro, who has for nearly fifteen [now twenty-five] years devoted himself, almost exclusively, to the study of the life and works of Galileo, and to whom was confided by the government the care of the national edition of the philosopher's works, under the auspices of the King of Italy. The orator kept his discourse within the limits marked out for him, speaking chiefly of Galileo at Padua. Constrained to leave the University of Pisa Galileo had been welcomed in that of Padua, where he found the 'natural home of his mind—a theatre worthy of his talents.' The conditions at Padua at that time were eminently favourable to Galileo's work, for the Venetian senate granted the lecturers the utmost liberty, and

experimental methods, which could not be learned from books, had been practised at the University for more than a century. Galileo had many opportunities for the development of his genius, both in the lecture-room and in the home, in the preparation of scientific publications, and in the workshops of scientific instrument-makers both in Padua and Venice. To Venice he frequently went, attracted by the means it afforded him for study; by that grand Arsenal, which had already been sung by Dante, and which in his famous Dialogues is spoken of by Galileo with admiration; but, above all, by the advantages he derived from scientific intercourse with eminent men who resided in the lagoon city. The culminating point of the discourse was naturally reached when the orator had to deal with the invention of the telescope, and with the astronomical discoveries made by means of it, the immediate result of which was the recall of Galileo to Tuscany. This did not aid him in his glorious career, or help to protect him from the attacks which were for a long time made on him by invidious adversaries. Even some of his own friends changed at once to implacable and dangerous enemies, and at last he was involved in all the miseries which sprang from the memorable trial before the Inquisition in Rome. This led the orator to recall the fact that, when the clouds assumed their most threatening aspect, the Venetian republic, forgetting with real magnanimity whatever resentment it might have felt at Galileo's abandonment of his chair at Padua, offered to reappoint him, and to print at Venice the work which had brought upon him so much trouble.

"After Professor Favaro's oration, discourses were delivered by the foreign delegates, Holmgren, Fayrer, Darwin, Tisserand, Lampe, Keller, Foerster, Sohncke, Blasing, Lemcke, Farey,

Lanczy, Schmourlo, and by Italian delegates, Nardi-Dei, Mantovani-Orsetti, and Del Lungo. Then followed the conferring of University honours, of which seven had been set apart by the council for seven men of science, one for each nation, all distinguished for their devotion to the studies in which Galileo excelled, viz., Schiaparelli, Helmholtz, Thomson, Newcomb, Tisserand, Bredichir, and Gylden. The degree of philosophy and letters was given to the Minister Martini; of natural philosophy, and of philosophy and letters, to the leading delegates. The ceremony was closed by the inauguration of a commemorative tablet in the large hall.

"Of the other festivities connected with the celebration it would be out of place to speak here, and it will be better to add a list of the publications which were issued on the occasion. The oration read in the great hall by Professor Favaro has been published, with the addition of twenty-five facsimiles of documents comprising the various decrees of the senate concerning Galileo; several autographic records of Galileo, chosen in order to give a more exact idea of what are the most precious materials for his biography; the frontispieces of the various publications issued by Galileo, and relating to the time of his sojourn in Padua; the geometric and military compass; the writing presenting the telescope to the Doge; and the first observations of the satellites of Jupiter. A portrait of the great philosopher, from a painting which represents him at the age of forty, taken in 1604, is prefixed.

"By favour of the University, there have also been published two other works, one containing all the notices of the studies at Padua in 1592, the other proving which was the house inhabited by Galileo and the place in which he made his

astronomical observations. The ancient Academy of Padua, among whose founders Galileo is numbered, has issued a publication in which are collected several works dedicated to his memory; and the students of the University have sought to perpetuate the remembrance of this festival by the publication of a 'unique number,' bringing together all the documents relating to the sojourn of Galileo in Padua. These publications will serve as suitable memorials of a great and most interesting celebration."

# BIBLIOGRAPHY

In the last years of his life, Galileo was anxious to have a complete edition of his works brought out in Latin, so as to be accessible to students of all nations. As we have already had occasion to show, this was impossible in Italy, owing to the most stringent orders of the Pope against the publication of *any* of his works, *edita et edenda* —an order which was only partially relaxed many years after his death. Thus, we have seen incidentally that in February 1635, Fra Fulgenzio Micanzio was prohibited by the local Inquisitor from bringing out in Venice a reprint of the treatise "On Floating Bodies," which does not in any way relate to the Copernican doctrine.

As, then, the presses of Italy were closed against him, Galileo had to look abroad for a publisher. In this way negotiations were opened, first about 1635, with Pierre Carcavi, a distinguished mathematician and *litterateur* of Paris, on the occasion of his visit to Florence; and two years later, with the Elzevirs of Leyden, through the intermediary of Micanzio in Venice. But, after much correspondence, and the translation into Latin of many pieces, these attempts fell through, one after the other, and for no reason that we can now know.

Von Gebler, who is usually very accurate, says (p. 281, "Galileo and the Roman Curia") that before August 1636, the Dialogues of 1632 had been translated into English, to the great delight of their author. If by this he means *published*, he must be mistaken, for the first English translations of the famous Dialogues and a few other pieces printed and published in England were those of

Thomas Salusbury in 1661-65, as noted in the "List of Works Consulted" which is appended to this bibliography. Galileo does not appear to have had any regular correspondents in England, for, amongst the thousands of letters in his *Carteggio*, there exists only one from George Fortescue[1]; but Hobbes, Milton, and, probably, other English travellers, were, of course, able to give him the gratifying news that his works were largely read in England; as, indeed, we now know from other indications. Thus, Tobie Matthew, writing to Bacon from Brussels, 21st April 1616, refers to the polemical letter of 1613 to Castelli; and in another letter, dated 14th April 1619, he introduces a Mr Richard White as a gentleman lately returned from Florence, where he had seen Galileo, and had obtained copies of his works, "On the Tides," "Sidereus Nuncius," "On Sun-Spots," and "On Floating Bodies"—all of which the writer was sending on to Bacon.[2]

Amongst the British Museum MSS. there are early English translations of two of Galileo's works as follows:—

Add. MSS. 23, 139.—"Of the profit which is drawen from the Art Mechanique and its Instruments; A Tract of Sigr. Galileo Galilei, Florentine. Raptim ex Italico in Anglicum sermonem transfusum. Novemb. 11, 1636, by Mr Robert Payen." This is evidently a translation of the "Scienza Meccanica" of 1594.

Harl. MSS. 6320.—"The Dialogues of Galileus, etc., upon the two Greatest Systems of the World, etc., with a dedicatory preface, and an explanatory introduction To the Discreete Reder." This MS. bears no date, only the initials W. N., which are supposed to be those not of the translator but of a former owner.[3]

[1] Dated London, 15th October 1629. Fortescue wrote, amongst other things, the "Feriae Academicae" (London, 1630), a series of essays in elegant Latin, in one of which, "Astrologorum Concessus," Galileo and his friends, Clavio and Griemberger, are the speakers.

[2] Bacon must also have heard a great deal about Galileo from his Venetian correspondents, Paolo Sarpi and Fulgenzio Micanzio.

[3] Galileo may have heard of this performance through Thomas Hobbes, who was travelling in Italy in 1635, and who then saw the great Florentine. The latter probably alludes to Hobbes in his letter

After Galileo's death, Viviani, then hardly twenty years old, resolved to carry out what he knew to be the ardent wish of his master, and at once set about collecting from relatives, friends, and disciples of the great dead, books, MSS., and documents, relating in any way to his subject. His intention was to publish the works in two languages in parallel columns, that is to say, to give a Latin version of those pieces first printed in Italian, and an Italian version of those which originally appeared in Latin. The collection was to be preceded by a comprehensive Life, of which he has left us the design—"Life of Galileo," in 3 books—I. "From Birth to Invention of the Telescope"; II. "From the Telescope to Death"; III. "Habitudes, Maladies, Sayings and Pastimes, Doctrines and Unwritten Opinions, Friends and Scholars, Letters of Distinguished Men to Galileo, Illustrations from his Printed Works." This was to be followed by the Works, in 4 volumes, 4to, in Latin and Italian, in double columns—I. "Astronomical Works"; II. "Mechanical, Physical, Mathematical Works"; III. "Suspected and Prohibited Works"; IV. "Posthumous Works, Collectanea, and Letters." A frontispiece (copper-plate) was to be prefixed to all the volumes; and portraits of Galileo, Salviati, and Sagredo, were to be given.[1]

Owing to ill-health and various obstacles, chief among them being the ecclesiastical prohibition of 1633, and the still active opposition of the Jésuits, Viviani was never able to carry out his great design; but through all his life

of 1st December 1635 to Micanzio, in which he says:—"In the last few days I have had many visitors from over the mountains, and amongst them one of the principal men of England, who told me that my unfortunate Dialogues had been translated into that language." This would fix the date of the above MS. at some time prior to the middle of 1634, the date of Hobbes' departure on his travels. It would also go to show that the translator was known to Hobbes. Who was he? I suggest this as a problem for "Notes and Queries."

[1] A short and very inaccurate biography, intended, probably, as a rough draft of the contemplated Life, was drawn up by Viviani in the form of a letter to Prince Leopoldo (afterwards Cardinal) de Medici, dated 29th April 1654. It was published for the first time in Salvini's "Fasti Consolari dell' Accademia Fiorentina," Florence, 1717.

he diligently added to his collection of the printed and MS. remains of his revered master.

Meanwhile an edition of Galileo's works appeared in Bologna, in 1655-56, in 2 volumes, 4to.[1] Although Viviani supplied the editor with much interesting material hitherto unpublished, this is little more than a reproduction of pieces already printed separately, with two notable exceptions, viz. the polemical letter of 1615 to the Grand Duchess Cristina di Lorena, and the Dialogues of 1632.

At Viviani's death (22nd September 1703), his fine library went by will to the Hospital of Santa Maria in Campo, Florence, and his great collection of Galilean remains, the result of sixty years' searching, passed into the hands of his nephew and heir, the Abbe Jacopo Panzanini. This man, ignorant or regardless of the value of his inheritance, made no attempt to utilise it, or to add to it, as he might easily have done in those days. He appears to have stowed the books and MSS. away in presses or cupboards, allowing, however, the use of them to students, some of whom, it is sad to say, forgot to return what they had borrowed. Thus, Tommaso Buonaventuri and Benedetto Bresciani, the editors of the first Florentine edition, were great sinners in this respect.[2] Their sin would, perhaps, not be so great had they made better use of the materials placed at their disposal. There is no order or method in the arrangement, and their work is in other respects imperfect; not only are the Dialogues of 1632 and other pieces banned by the Inquisition omitted, but some of those which are included are not published in their integrity.

A better edition was brought out in Padua in 1744.[3] Here also many pieces, already published, are omitted, but the Dialogues of 1632 are given "with ecclesiastical permission." The editor, however, appears to have been

[1] "Opere di Galileo, etc. In questa nuova editione insieme raccolte, e di varii trattati non più stampati accresciute."

[2] "Opere di Galileo, etc. Coll' Aggiunta di vari trattati non più dati alle stampe." 3 vols. 4to. Florence, 1718.

[3] "Opere di Galileo, etc. Accresciute di Molte Cose Inedite." 4 vols. 4to. Padua, 1744.

obliged to prefix some saving clauses. The sentence of 1633 and Galileo's abjuration are reprinted, and are followed by a declaration that the theory of the double motion of the earth can and must be regarded only as a mathematical hypothesis to facilitate the explanation of certain natural phenomena. Then follows, for greater security I suppose, Father Calmet's essay,[1] in which the Scriptural passages relating to the order of the world ought, presumably, to be interpreted in the orthodox fashion. As a matter of fact, however, the learned Father's line of argument differs little from that of Galileo. He seeks to show that the Bible does not propound any astronomical system whatever; that if it does, it is the popular cosmography of the Hebrews, from which it often borrows expressions or images, but without guaranteeing their accuracy; that this cosmography is scientifically untenable, and, moreover, differs essentially from that of Ptolemy and the Peripatetics, and, therefore, people have no right to invoke the Scriptures in support of the latter. In fact, in the first centuries of Christianity, the Ptolemaic doctrine of a round earth was held by some fanatics as heretical, being opposed to the Hebrew and Scriptural presentment of the earth as a plain surface over which the heavens are spread in tent fashion.

A few years after the appearance of the Paduan edition an accident befell the Galilean papers, from which they, or rather what remained of them, were saved by, so to speak, a miracle. The story is told by Professor Giovanni Targioni-Tozzetti in his "Notizie degli Aggrandimenti delle Scienze Fisiche in Toscana" (Florence, 1780), and by Nelli in his "Vita e Commercio Letterario di Galileo Galilei" (Lausanne, 1793).

In the spring of 1750, the celebrated Dr Giovanni Lami, Keeper of the Riccardian Library in Florence, going one day, according to his wont, to lunch with some friends in the suburbs (at the "Osteria del Ponte alle Mosse"), and passing through the market-place, suggested

[1] "Dissertation sur le Système du Monde des Anciens Hébreux." Paris, 1720.

to Gio. Battista Nelli (his companion) to procure a Bologna sausage from the shop of Cioci, a pork-butcher then noted for his wares. Nelli did so, and brought away the purchase wrapped in an old MS. paper. Arrived at the tavern, he called for a plate, and, unrolling his sausage, remarked that the wrapper was a letter in Galileo's handwriting! Suppressing his surprise as well as he could, he cleaned the paper and put it into his pocket, without saying a word to Lami. After returning to the city, Nelli got rid of his friend, and flew to the pork-seller's shop, where he learnt that a servant, whom the proprietor did not know, brought him from time to time similar writings which he bought by weight as waste paper. Nelli purchased all that he then had, and, after watching for several days the return of the unknown domestic with another bundle, had at last the good fortune to meet him, and to learn the quarter whence the papers came. This was no other than Viviani's house in Via dell' Amore [now Via San Antonino] then occupied by Carlo and Angelo Panzanini, nephews and heirs of the Abbe, who died in 1733. After some judicious enquiries Nelli found that it was the brothers Panzanini themselves who were guilty of the atrocity of selling from time to time bundles of these precious papers, and with a little management he procured what remained in their hands for the sum of eighty-eight scudi (about £20). These comprised a great number of MSS. of Galileo, Viviani, Torricelli, and Borelli, and a number of mathematical instruments belonging to Viviani. At the same time he became the possessor of the emerald ring which Prince Cesi gave to Galileo on his election as a member of the Accademia dei Lincei in 1611, and a collection of designs by the most celebrated architects of Italy.

To this important acquisition so extraordinarily brought about, Nelli added, in 1754, a number of portraits of eminent mathematicians, forming part of the collection made by Viviani, another part of which came, at about the same time, into the hands of the astronomer, Perelli. It would seem that the Panzaninis had sold these many

years previously, besides a great number of Galileo's MSS., books full of marginal annotations in his autograph, and letters from his correspondents. Most of these were purchased, either directly from the Panzaninis, or from third parties, by Felici, Cocchi, Capponi, Nelli (in 1754), and more recently by Campori. Ultimately all these collections were acquired by the Tuscan Government, and, with the nucleus which already existed, gathered from Florentine libraries and from other public and private sources, now form the grand collection of Galilean books and MSS. in the Biblioteca Nazionale in Florence. It is comprised in some 303 large volumes, and arranged under five heads or classes as follows :—

| | |
|---|---|
| 1. Before the time of Galileo | 10 vols. |
| 2. MSS. of Galileo . . | 86 vols. |
| 3. Contemporaries of Galileo | 11 vols. |
| 4. Disciples of Galileo . . | 148 vols. |
| 5. After the time of Galileo | 48 vols. |

Besides this collection, Professor Favaro, the learned Director of the new edition of Galileo's Works now in course of publication, has catalogued over 1200 MSS. and documents relating to Galileo (many of which are his autographs) dispersed in the public and private libraries of Europe.[1]

Notwithstanding the zeal and industry of collectors, many of Galileo's papers and letters are missing. Some of these are mentioned in pp. 37, 120, 156, 194, *ante*, to which we may now add the loss of his later notes on (1) "The Mechanical Problems of Aristotle," and (2) "On the Movements of Animals," on which he was engaged only a short time before his fatal illness. No doubt many valuable papers were lost through the sordid action of the Panzaninis, and Viviani tells us that others were destroyed by Galileo's grandson, Cosimo, who conceived that in so

[1] "Materiali per un Indice dei MSS. e Documenti Galileiani non posseduti dalla Biblioteca Nazionale di Firenze." Raccolti per cura di Antonio Favaro, Venice, 1894.

doing he was offering up a proper sacrifice before devoting himself to the life of a missionary priest.[1]

During the years 1808 to 1811 a new edition of Galileo's Works appeared in Milan, in 13 volumes, 8vo, of which it is only necessary to say that the first 12 volumes are a simple reprint of the Paduan edition, whilst the 13th and last contains matter not found in that collection, it is true, but yet nothing that had not been published before. Another edition, and the worst of all, appeared in Milan in 1832, and forms volumes xx. and xxi. of Bettoni's "Biblioteca Enciclopedica Italiana."

The more recent editions of Albèri and Favaro are noted in detail in the "List of Works Consulted" subjoined to this notice.

A bibliography would not be complete without a reference to the extraordinary collection of forged documents, with which the French Academy of Sciences was convulsed in the years 1867-1869. They were acquired by Michel Chasles, a member of the Academy, and by him presented to that body in batches. They consisted of letters and documents bearing the names of Galileo, Viviani, Pascal, Newton, Milton, Huygens, Louis XIV., and other well-known persons of the period; and they went to show, amongst other startling things, (1) that Pascal borrowed from Galileo the idea of universal gravitation, and that Newton in his turn borrowed from both, without acknowledgments; and (2) that Galileo's blindness was feigned in order to induce the Inquisition authorities to relax their surveillance; and that he really became blind only a short time before death.

The briefest *résumé* of these papers will suffice here, as the curious reader will find them, and the discussions to which they gave rise, fully reported in the *Comptes*

[1] Professor Favaro thinks there is little or no foundation for this charge, and concludes, after reviewing the evidence, that if Cosimo did burn any papers of his grandfather, they were such as were of no importance, and of which Viviani already had copies, or, and this is the more likely, they were his own youthful lucubrations of which his later and ascetic temper could not approve.

*Rendus* for the years mentioned, and the history of the forgeries in Bordier and Mabille's "Une Fabrique de Faux Autographes, ou Récit de l'Affaire Vrain Lucas."[1]

It would appear from these documents that in the last years of his life, Galileo discovered a satellite of Saturn and made other astronomical observations, which, with some found in Kepler's MSS. (which had come into Galileo's hands), exceeded in extent and accuracy the subsequent observations of Cassini, Bradley, and Pound, and of which Newton availed himself in 1725, in the third and perfected edition of his "Principia." Furthermore: Galileo had deduced theoretically, from Kepler's Second Law, that the reciprocal attraction of the heavenly bodies ought to be in the inverse ratio of the squares of the distances. He communicated this discovery, as also his latest astronomical observations and those of Kepler, to Pascal, and upon these materials the latter based his Celestial Mechanics, including the calculation of the planetary masses, and wrote a treatise on the subject, a copy of which he sent to Galileo in 1641.

In 1652, Boyle put Pascal in communication with Newton [then of the mature age of ten years!], and in 1654, Pascal communicated to Boyle and Newton the aforesaid observations of Galileo and Kepler, together with his own Celestial Mechanics, and calculations of the planetary masses. In 1687, Newton published (in the "Principia") Pascal's work as his own, but spoilt it by the employment of data less accurate than those of Galileo and Kepler, of which, indeed, he made no use until 1725 (as stated above), or seventy-one years after receiving them; and then, instead of mentioning Galileo and Kepler, to whom he was really indebted, he quoted the work of later astronomers who had arrived at similar results. The communications made to Newton by Pascal, and Newton's usurpation of them were facts known to many scientific men in France and England; but nothing was said about them until Newton had committed a

[1] Paris, 1870. On the forgeries of Vrain Lucas is founded Alphonse Daudet's novel, "L'Immortel."

further imprudence. In a letter to Huygens he appears to have used some disdainful language about Pascal; Huygens thereupon brought the whole matter before the French Academy of Sciences, that jealous body complained to Louis XIV., who in his turn complained to James II. of England. The result was that Newton withdrew his defamatory remarks, Louis XIV. expressed his gratitude to Newton (to whom, strange to say, was left all the glory which belonged to Pascal and Galileo), and everybody was content! The affair was hushed up, and soon entirely forgotten, until revived by the publication of M. Chasles' wondrous "find." So much for the Galileo-Pascal-Newton story.

As regards the fable of Galileo's blindness, it would seem, from his letters and those of Viviani, Milton, and others, that his sight became enfeebled only in 1637-38; that up to September 1641 he was able to read and write, and only complained of fatigue of the eyes; and that he became totally blind only towards the end of 1641, that is, a few weeks before death. Galileo, who, probably, never wrote a line in French, is made to say, in a letter of 28th November 1639, to Louis XIII. of France:—

> "Du reste je veux bien assurer Vostre Majesté que, quoique ce soit pour moy une grande privation de ne pouvoir continuer mes observations astronomiques, je commence à my rèsigner, et je m'estime encore heureux qu'à mon age, et après tant de tribulations, je puisse encore lire et escrire, ce qui est pour moy une grande satisfaction. Quant à certains propos que des gens tiennent et font circuler à cet ègard, je ne cherche nullement à les démentir, d'autant plus que c'est un moyen d'estre moins obsédé par mès ennemis, c'est à dire, par les Inquisiteurs, qui ne cessoint de me faire surveiller. Nous nous sommes mesme servi du prétexte de cécité pour qu'on me laisse plus en repos et à moy mesme."

As to this fable, there are two well-established facts, which would seem to lend it some little support—(1) It is certain that Galileo's blindness was due to glaucoma. (2) In recent years a letter of Alberto Galilei (nephew) to

Galileo, dated 19th April 1640, has been brought to light, from which it would appear that towards the end of 1639 Galileo had recovered somewhat the use of his eyes. Professor Favaro, however, says (and there can be no better judge) that, in all probability, the passage is either an *equivoque*, or a question of being able to distinguish, more or less, the day from the night.[1]

[1] "Galileo e Suor Maria Celeste," p. 221.

# LIST OF THE PRINCIPAL WORKS CONSULTED IN PREPARING THE PRESENT VOLUME.

Le Opere di GALILEO GALILEI, prima edizione completa,[1] condotta sugli autentici manoscritti palatini, e dedicata a S. A. I. e R. Leopoldo II granduca di Toscana.—*Firenze, società editrice fiorentina*, 1842-1856. *Tomi XV e uno di supplemento.*

Patrono dell' edizione: S. A. I. e R. il granduca LEOPOLDO II.
Direttore: EUGENIO ALBÈRI.
Coadiutore: CELESTINO BIANCHI, per i primi sette volumi.

*Tomo primo* (1842).

Lettera dedicatoria a S. A. I. e R. il granduca Leopoldo II, patrono dell' edizione.

Prefazione generale.

Dialogo dei due massimi sistemi del mondo, tolemaico e copernicano.

*Tomo secondo* (1843).

Prefazione con elenco ragionato degli oppositori al sistema copernicano.

Lettera di GALILEO a Iacopo Mazzoni, del 30 maggio 1597.

Lettera di GALILEO al p.e Benedetto Castelli del 21 dicembre 1613.

Lettera di GALILEO a monsignor Dini del 16 febbraio 1614 ab inc.

Lettera di GALILEO al medesimo del 23 marzo 1614 ab inc.

Lettera di GALILEO alla granduchessa Cristina di Lorena del 1615.

Lettera di GALILEO a Francesco Ingoli, nella primavera del 1624.

Esercitazioni filosofiche di ANTONIO ROCCO intorno al dialogo dei massimi sistemi.

[1] This is by no means a complete, or even, so far as it goes, an accurate, presentation of Galileo's works and writings. This can be seen by comparing it with Favaro's national edition, now in course of publication, and of which twelve out of twenty volumes have already appeared.

Postille di GALILEO alle suddette esercitazioni.

Discorso di LODOVICO DELLE COLOMBE contro al moto della Terra.

Postille di GALILEO al suddetto discorso.

Discorso sopra il flusso e reflusso del mare.

*Tomo terzo* (1843).

Trattato della sfera o cosmografia.

Sidereus Nuncius.

Lettere intorno alle apparenze della Luna.

De phaenomenis in orbe Lunae etc., auctore JULIO CESARE LA GALLA.

Postille di GALILEO all' opera suddetta.

Lettere intorno alle macchie solari.

*Tomo quarto* (1844).

Ai lettori.

De tribus cometis anni 1618 disputatio astronomica, publice habita in collegio romano societatis Jesu ab uno ex patribus eiusdem societatis.

Discorso delle comete di MARIO GUIDUCCI.

Libra astronomica ac philosophica etc., auctore LOTHARIO SARSIO sigensano [HORATIO GRASSIO salonensi].

Postille di GALILEO alla Libra astronomica.

Il Saggiatore di GALILEO.

Ratio ponderum librae ac simbellae etc., auctore LOTHARIO SARSIO.

Postille di GALILEO alla suddetta opera.

*Tomo quinto* (Parte prima, 1846).

Alcuni esemplari hanno la prima parte del tomo quinto, e la prima sezione della seconda in lingua italiana, altri in latino.

Prefazione di EUGENIO ALBÈRI nella quale si dimostra che tutti i lavori condotti da Galileo intorno i Satelliti di Giove, e che da due secoli si reputavano perduti, esistono fra i manoscritti galileiani della i. e r. biblioteca palatina de' Pitti.

Tavole dei moti medi de'Satelliti di Giove istituite da GALILEO ecc.

Osservazioni originali e calcoli intorno i Satelliti di Giove.

Giustificazioni delle lacune che si riscontrano tra le osservazioni di GALILEO intorno i Satelliti di Giove.

Calcoli ed effemeridi.

Nota e conclusione.

(Parte seconda, 1853).

Lavori del padre RENIERI intorno ai Satelliti di Giove.

Le operazioni astronomiche di GALILEO.

Frammenti di tre lezioni di GALILEO intorno la stella nuova del 1604.

Frammenti astronomici di GALILEO.

KEPLERI Dissertatio in Nuncium sidereum.

KEPLERI Narratio de observatis a se Satellitibus Jovis.

KEPLERI Periochae ex introductione in Martem.

Lettera del p. FOSCARINI sul sistema copernicano.

CAMPANELLAE Apologia pro Galilaeo.

Dissertazione del p. CALMET intorno alla cosmogonia degli antichi.

Lettera di MARIO GUIDUCCI al p. Galluzzi intorno le comete.

KEPLERI Spicilegium ex trutinatore Galilaei.

Appendix ad spicilegium.

KEPLERI Admonitio ad bibliopolas.

Discorso di A. DE FILIIS sulle Macchie solari di Galileo.

*Tomo sesto a decimo* (1847-1853).

Contengono un avvertimento e l'epistolario, composto di 1376 lettere, dal 1588 al 1642, diviso in due parti. La prima di due volumi (VI e VII, 1847-1848) comprende le lettere di GALILEO che sono 296. L'altra in tre volumi (VIII, IX, e X, 1851-1853) che comprende le lettere a lui dirette; in numero di 931, e fra terzi a lui relative, che sono 149.

*Tomo undecimo* (1854).

Avvertimento all' opera seguente.

Sermones de motu gravium di GALILEO.

Della scienza meccanica di GALILEO.

Note e proposizioni intorno le meccaniche di VINCENZO VIVIANI.

Trattato di fortificazione di GALILEO con avvertimento.

Le operazioni del compasso geometrico e militare di Galileo con avvertimento.

Usus et fabrica circini proportionis etc. opera et studio Balthasaris Caprae.

Difesa di Galileo contro alle calunnie del Capra.

*Tomo duodecimo* (1854).

Avvertimento.

Discorso di Galileo delle cose che stanno in su l'acqua o che in quella si muovono.

Lettera di Tolomeo Nozzolini a monsignor Marzimedici nella quale si promuovono alcune difficoltà intorno al libro di Galileo.

Lettera di Galileo al Nozzolini in risoluzione delle accennate difficoltà.

Discorso apologetico di Lodovico delle Colombe intorno al suddetto discorso dei galleggianti di Galileo.

Considerazioni di Vincenzo di Grazia intorno al medesimo discorso.

Risposta di Galileo, sotto nome del p. Castelli, alle opposizioni di Lodovico delle Colombe e di Vincenzo di Grazia.

Note al discorso dei galleggianti.

Esperimenti del cav. Gio. Batta Venturi intorno ai galleggianti.

*Tomo tredicesimo* (1855).

Avvertimento.

Discorsi e dimostrazioni matematiche intorno a due nuove scienze attinenti alla meccanica ed ai movimenti locali; altrimenti detti "Dialoghi delle nuove scienze."

*Tomo quattordicesimo* (1855).

Illustrazioni del Viviani e del Grandi ai Dialoghi delle nuove scienze.

Trattato delle resistenze principiato da Vincenzo Viviani per illustrare le opere di Galileo, compiuto e riordinato dal p. Guido Grandi.

Note del p. Grandi al trattato del moto naturalmente accelerato.

Scienza universale delle proporzioni, spiegata da Galileo nella quinta giornata, con nuovo ordine distesa dal Viviani.

Componimenti minori e frammenti diversi in materie scientifiche di GALILEO.

La bilancetta ecc. di GALILEO.

Note del MANTOVANI, del CASTELLI, e del VIVIANI alla bilancetta.

Parere sopra una macchina per alzare acqua.

Lettere intorno alla stima di un cavallo.

Parere intorno all' angolo del contatto.

Considerazioni sopra il giuoco de' dadi.

Risposta al problema: onde avvenga che l' acqua a chi v' entra appaia prima fredda e poi calda più dell' aria temperata.

Parere su di una macchina da pestare.

Pensieri sulla confricazione.

Avvertenza intorno al camminare del cavallo.

Theorica speculi concavi sphaerici.

Problemi vari.

Pensieri vari.

Dell' oriuolo a pendolo, lettera di VINCENZO VIVIANI.

*Tomo quindicesimo* (1856).

Due lezioni di GALILEO intorno alla figura, sito, e grandezza dell' Inferno di Dante precedute da un avvertimento degli editori.

Postille e correzioni all' Orlando furioso precedute da un avvertimento degli editori.

Considerazioni alla Gerusalemme liberata.

Due lettere a Francesco Rinuccini nelle quali si paragona il Tasso con l'Ariosto.

Discorso di GIUSEPPE ISEO sopra il poema di M. Torquato Tasso.

Capitolo in biasimo della toga.

Quattro sonetti.

Abbozzo di una commedia.

Racconto istorico della vita di Galileo scritto da VINCENZO VIVIANI.

Bibliografia Galileiana.

Aggiunte e correzioni a diversi volumi della collezione.

*Supplemento* (1856).

Avvertimento.

E. ALBÈRI. Esame della biografia di Galileo scritta da F. ARAGO.

Lettere (186) inedite dirette a Galileo dal 1592 al 1641, fra le quali a pag. 11 una di Galileo all' abate Giugni da Venezia, 11 giugno 1605.

Appendice relativa al processo di Galileo.

E. Albèri. Dell'orologio a pendolo di Galileo e di due recenti divinazioni del meccanismo da lui immaginato.

Due lettere importantissime di Galileo, una relativa alla sua condanna, l'altra ai tentativi da lui fatti per la misura della cicloide.

Le Opere di Galileo Galilei. Edizione Nazionale sotto gli auspicii di S. M. il Re d'Italia.—Direttore, Antonio Favaro. Coadiutore letterario, Isidoro del Lungo. Assistente per la cura del testo, Umberto Marchesini.—Consultori, V. Cerruti, A. Genocchi (✠). G. Govi (✠). G. V. Schiaparelli.—Firenze, tip. G. Barbèra, 1890-1902. . . .

Volume Primo (1890).—Iuvenilia.—Theoremata circa centrum gravitatis solidorum.—La Bilancetta.—Tavola delle proporzioni delle gravità in specie de i metalli e delle gioie pesate in aria e in aqqua.—Postille ai libri de sphaera et cylindro di Archimede.—De motu.

Volume Secondo (1891).—Breve instruzione all' architettura militare.—Trattato di fortificazione.—Le Mecaniche.—Lettera a Iacopo Mazzoni.—Trattato della Sfera ovvero Cosmografia.—De motu accelerato.—Frammenti di lezioni e di studi sulla nuova stella dell' ottobre 1604.—Consideratione astronomica circa la stella nova dell' anno 1604 di Baldesar Capra, con postille di Galileo.—Dialogo de Cecco di Ronchitti da Bruzene in perpuosito de la stella nuova.—Del compasso geometrico e militare: saggio delle scritture antecedenti alla stampa.—Le operazioni del compasso geometrico e militare.—Usus et fabrica circini cuiusdam proportionis, opera et studio Balthasaris Caprae; con postille di Galileo.—Difesa contro alle calunnie et imposture di Baldessar Capra.—Le matematiche nell' arte militare.

Volume Terzo. Parte prima (1892).—Sidereus Nuncius.—Ioannis Kepleri Dissertatio cum Nuncio Sidereo.—Martini Horky Brevissima peregrinatio contra Nuncium sidereum.—Quatuor problematum contra Nuncium sidereum confutatio per Ioannem Wodderbornium.—Ioannis Kepleri Narratio de observatis a se quatuor Iovis satellitibus.—Ioannis Antonii Roffeni Epistola apologetica contra peregrinationem Martini Horkii.—

Dianoia astronomica, optica, physica, auctore Francisco Sitio; con postille di Galileo.—Di Ludovico delle Colombe contro il moto della terra; con postille di Galileo.—Nuntius Sidereus Collegii romani.—De lunarium montium altitudine problema mathematicum.—Iulii Caesaris La Galla De phaenomenis in orbe lunae novi telescopii usu nunc iterum suscitatis; con postille di Galileo.

Volume Quarto (1894).—Diversi fragmenti attenenti al trattato delle cose che stanno su l'acqua.—Discorso intorno alle cose che stanno in su l'acqua o che in quella si muovono.—Considerazioni di Accademico Incognito; con postille e frammenti della risposta di Galileo.—Operetta intorno al galleggiare dei corpi solidi di Giorgio Coresio.—Errori di Giorgio Coresio nella sua operetta del galleggiare della figura raccolti da d. Benedetto Castelli. Con correzioni ed aggiunte di Galileo.—Lettera di Tolomeo Nozzolini a monsignor Marzimedici arcivescovo di Firenze.—Lettera a Tolomeo Nozzolini.—Discorso apologetico di Lodovico delle Colombe.—Considerazioni di Vincenzio di Grazia.—Frammenti attenenti alla scrittura in risposta a Lodovico delle Colombe e Vincenzio di Grazia.—Risposta alle opposizioni di Lodovico delle Colombe e di Vincenzio di Grazia contro al trattato delle cose che stanno su l'acqua o che in quella si muovono.

Volume Quinto (1895).—Apellis latentis post tabulam tres epistolae de maculis solaribus.—Apellis latentis post tabulam de maculis solaribus et stellis circa Iovem errantibus accuratior disquisitio; con postille di Galileo.—Istoria e dimostrazioni intorno alle macchie solari e loro accidenti, comprese in tre lettere scritte a Marco Velseri.—Frammenti attenenti alle lettere sulle macchie solari.—Lettera a D. Benedetto Castelli.—Lettere a mons. Piero Dini.—Lettera a madama Cristina di Lorena granduchessa di Toscana.—Considerazioni circa l'opinione copernicana.—Discorso del flusso e reflusso del mare.—Francisci Ingoli De situ et quiete Terrae disputatio.—Proposte per la determinazione della longitudine.

Volume Sesto (1896).—De tribus cometis anni MDCXVIII disputatio astronomica publice habita in Collegio Romano Societatis Jesu ab uno ex patribus eiusdem Societatis.—Discorso delle comete, con alcuni frammenti ad esso attenenti.—Lotharii Sarsii Sigensani Libra astronomica ac philosophica; con postille di Galileo.—Lettera di Mario Guiducci al P. Tarquinio Galluzzi.

—Il Saggiatore.—Lotharii Sarsii Sigensani Ratio ponderum et simbellae; con postille di Galileo.—Lettera a Francesco Ingoli in risposta alla Disputatio de situ et quiete terrae.—Scritture concernenti il quesito in proposito della stima d'un cavallo.—Scritture attenenti all' idraulica.

Volume Settimo (1897).—I due massimi sistemi del mondo.—Frammenti attenenti al dialogo sopra i due massimi sistemi del mondo.—Dal libro di G. B. Morin "Famosi et Antiqui Problematis de Telluris Motu vel Quiete," con le note di Galileo.—Esercitazioni filosofiche di A. Rocco, con postille di Galileo.

Volume Ottavo (1898).—Le nuove scienze.—Della forza della percossa.—Sopra le difinizioni delle proporzioni d'Euclide.—Frammenti attenenti ai discorsi e dimostrazioni matematiche intorno a due nuove scienze.—Le operazioni astronomiche.—Lettera al Principe Leopoldo di Toscana in proposito del cap. L. del "Litheosphorus" di Fortunio Liceti.—Frammenti attenenti alla lettera al Principe Leopoldo di Toscana.

*Scritture di data incerta.*

A proposito di una macchina con gravissimo pendolo adattato ad una leva.—A proposito di una macchina per pestare—Di alcuni effetti del contatto e della confricazione.—Sopra le scoperte de i dadi.—Intorno la cagione del rappresentarsi al senso fredda o calda la medesima acqua a chi vi entra asciutto o bagnato.—Problemi.—Nell' arte navigatoria.—Frammenti geometrici.

Volume Nono (1899).—La figura, sito, e grandezza dell'Inferno di Dante.—Considerazioni al Tasso.—Postille all' Ariosto.—Argomento e traccia d'una commedia.—Poesie e Frammenti.—Canzone di Andrea Salvadori per le Stelle Medicee, scritta e corretta di propria mano da Galileo.—Saggio di alcune esercitazioni scolastiche di Galileo.

Volume Decimo (1900)—Carteggio, 1574-1610.
Volume Undecimo (1901).—Carteggio, 1611-1613.
Volume Duodecimo (1902).—Carteggio, 1614-1619.

*In course of publication.*

Volume Decimoterzo.—Carteggio, 1620-1628.
Volume Decimoquarto.—Carteggio, 1629-1632.
Volume Decimoquinto.—Carteggio, 1633.
Volume Decimosesto.—Carteggio, 1634-1636.

Volume Decimosettimo.—Carteggio, 1637-1638.
Volume Decimottavo.—Carteggio, 1639-1642.[1]
Volume Decimonono.—Documenti.
Volume Ventesimo.—Indici.

Besides editing this splendid collection, which alone is a monumental work, Professor Favaro has written considerably over one hundred papers, essays, and detailed studies, each illustrative of some point in the life and writings of Galileo. Some of these have been published in book form, but far the greater part is scattered through the journals of learned societies in Italy, dating back to 1878. Fortunately for the student, much of the information they contain is reproduced in the numerous (historical and critical) introductions and notes which enrich the new national edition of Galileo's works and correspondence. In the following list we give a few as of general interest, besides which some other papers by the same author will be found quoted in the body of our work.

FAVARO, PROF. ANTONIO. "Galileo e lo Studio di Padova," 2 vols. Florence, 1883.

—— "Scampoli Galileiani." 12 Series (*Atti e Memorie della Accademia di Scienze, Lettere, ed Arti in Padova*). 1886-1897.

—— "Documenti Inediti per la Storia dei Manoscritti Galileiani nella Biblioteca Nazionale di Firenze." Rome, 1886.

—— "Miscellanea Galileiana Inedita: Studi e Ricerche" (*Memorie del R. Istituto Veneto di Scienze, Lettere, ed Arti*). 1887.

—— "Galileo Galilei e Suor Maria Celeste." Florence, 1891.

—— "Nuovi Studi Galileiani" (*Memorie del R. Istituto Veneto di Scienze, Lettere, ed Arti*). 1891.

—— "Galileo ed il suo Terzo Centenario Cattedratico nell' Università di Padova" (*Natura ed Arte*). Milan, 1893.

*The following items are arranged in chronological order.*

VIVIANI, VINCENZIO. "Racconto Istorico della Vita di Galileo." Florence, 1654 (printed in vol. xv. of Albèri's Edition, quoted above).

[1] The *Carteggio* contains considerably over 4000 letters from, to, and concerning, Galileo, of which 420 are Galileo's.

SALUSBURY, THOMAS. "Mathematical Collections and Translations," 2 vols. London, 1661 and 1665.

*Contains following works of Galileo*:—

(1) "On the System of the World."
(2) "Epistle to the Grand Duchess, Mother, Concerning the Authority of Scripture in Philosophical Controversies."
(3) "Mathematical Discourses and Demonstrations touching Two New Sciences, Pertaining to Mechanics and Local Motions."
(4) "On Mechanics, with some Additional Pieces."
(5) "Discourse on Natation."

*Note.*—Part II. of the Second Volume contains a "Life of Galileo," in five books. Most of the copies of this part were destroyed in the Great Fire of London, and very few perfect copies now exist; that in the British Museum is imperfect.

WESTON, THOMAS. "Mathematical Discourses Concerning Two New Sciences relating to Mechanics and Local Motion, in Four Dialogues, by Galileo Galilei, Chief Philosopher and Mathematician to the Grand Duke of Tuscany. With an Appendix Concerning the Centre of Gravity of Solid Bodies." Done into English from the Italian. London, 1730.

NELLI, GIO. BATISTA CLEMENTE. "Vita e Commercio Letterario di Galileo Galilei," 2 vols. Lausanne, 1793.

MONTUCLA, J. F. "Histoire des Mathématiques depuis leur Origine jusqu'à Nos Jours," 3 vols. Paris, 1802.

NEUMAYR, ANTONIO. "Illustrazione del Prato della Valle, ossia della Piazza delle Statue di Padova," 2 parts. Padua, 1807.

VENTURI, GIAMBATISTA. "Memorie e Lettere Inedite Finora o Disperse di Galileo Galilei," 2 parts. Modena, 1818-1821.

MÖLL, Dr G. "On the first Invention of Telescopes, collected from the Notes and Papers of the late Prof. Van Swinden" (*Journal of the Royal Institution*). London, 1831.

DRINKWATER-BETHUNE, J. E. "Life of Galileo. With Illustrations of the Advancement of Experimental Philosophy." (*Library of Useful Knowledge*). London, 1833.

POWELL, BADEN. "Historical View of the Physical and Mathematical Sciences from the Earliest Ages to the Present Times' (Lardner's *Cabinet Cyclopædia*). London, 1834.

WHEWELL, WILLIAM. "History of the Inductive Sciences," 3 vols. London, 1837; or later editions.

BREWSTER, SIR DAVID. "Martyrs of Science, or Lives of Galileo, Tycho Brahé, and Kepler." London, 1841.

The Biography of Galileo first appeared in Lardner's Cabinet Cyclopædia—"Eminent Literary and Scientific Men of Italy, Spain, and Portugal," 2 vols. London, 1835.

LIBRI, GUILLAUME. "Histoire des Sciences Mathématiques en Italie depuis la Renaissance des Lettres jusqu'à la fin du 17 Siècle," 4 vols. Paris, 1841.

—— "Essai sur la Vie et les Travaux de Galilée." Paris, 1841. (Reprint from the *Revue des Deux Mondes* of 15th July 1841).

ROSINI, GIOVANNI. "Descrizione della Tribuna di Galileo in Firenze." Florence, 1841.

ANTINORI, VINCENZO. "Notices sur La Tribune de Galilée." Florence, 1843. (Reprinted 1861).

GRANT, ROBERT. "History of Physical Astronomy." London, 1852.

ARAGO, FRANÇOIS. "Oeuvres Complètes, de," edited by J. A. Barral, 3 vols. Paris, 1855.

CHASLES, PHILARÈTE. "Galileo Galilei: Sa Vie, Son Procès, et Ses Contemporains." Paris, 1862.

VARIOUS AUTHORS. "Nel Trecentesimo Natalizio di Galileo in Pisa, 18 Febbraio 1864." Pisa, 1864.

PARCHAPPE, MAX. "Galilée, Sa Vie, Ses Découvertes, et Ses Travaux." Paris, 1866.

PONSARD, FRANÇOIS. "Galilée: Drame en Trois Actes en Vers." Paris, 1867.

MARTIN, TH. HENRI. "Galilée: Les Droits de la Science, et la Méthode des Sciences Physiques." Paris, 1868.

FIGUIER, LOUIS. "Vies des Savants Illustres depuis l'Antiquité jusq'au 19 Siècle," 4 vols. Paris, 1869.

ANONYMOUS (MRS OLNEY). "Private Life of Galileo. Compiled Principally from his Correspondence and that of his Eldest Daughter, Sister Maria Celeste, Nun in the Franciscan Convent of St Mathew in Arcetri." London, 1870.

NEWCOMB, SIMON. "Popular Astronomy. London, 1878."

CLERKE, A. M. "Biography of Galileo," in *Ency. Brit.* Ninth Edition. Edinburgh, 1879.

GEBLER, KARL VON. "Galileo Galilei and the Roman Curia." (Mrs Sturge's Translation). London, 1879.

BALL, SIR R. S. "Story of the Heavens." London, 1885; or later editions.

WEGG-PROSSER, F. R. "Galileo and his Judges." London, 1889.
GOVI, GILBERTO. "The Compound Microscope invented by Galileo." (*Journal of the Royal Microscopical Society*). London, 1889.
BERRY, ARTHUR. "Short History of Astronomy." London, 1898.
GORI, PIETRO. "Le Preziosissime Reliquie di Galileo Galilei." Florence, 1900.
NEWCOMB, SIMON. "The Stars." London, 1901.

# INDEX

PRINTED AT THE EDINBURGH PRESS, 9 AND 11 YOUNG STREET.